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THE STORAGE BATTERY QUESTION.

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[*A lecture delivered before the Franklin Institute, January 2, 1893.*]

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

During the past six years I have had the honor, on more than one occasion, to call the attention of the members of the Institute to the subject of storage batteries, or electrical accumulators. On these occasions I have endeavored to give you some idea of the process of manufacturing accumulators and their use in electric lighting or electric traction, a paper on the latter subject having been presented at your June meeting, 1892.

Notwithstanding the serious setbacks the accumulator business has suffered during the last five years, owing to the unfortunate litigation in which it has been involved, the interest in the subject instead of abating is so great to-day that electrical engineers, after condemning for years the use

of storage batteries, are compelled to recognize them, and not only to recognize them, but to adopt them in almost every branch of electrical engineering.

This being the case, it is manifest that a more intimate knowledge of the construction, and operation of a storage battery is desirable, and it will be, therefore, my purpose to-night to call your attention first to the construction of a storage battery, and second to describe briefly the many uses to which a storage battery can be applied. Of course, the subject does not admit of any brilliant or marvellous experiments, such, for example, as Mr. Tesla will show you, but as the storage battery will soon be a factor entering into our daily life, you may be interested in noting these applications, and what is still more valuable, they may have that suggestive influence which will enable some of you to devise new methods and discover new fields of usefulness.

History.—A storage battery is not a new thing. Away back in the early days of this century, a French chemist, named Gautherot, observed that the plates of a voltameter gave a reverse current. A voltameter is an instrument for measuring the galvanic current by means of the chemical action produced, and Gautherot observed that after a galvanic current had been passing through the plates of a voltameter for some time, and was then discontinued, that if he connected the terminals of the voltameter a current was obtained in the reverse direction, and this is the germ of the secondary battery. If, for example, a current of electricity is passed between two lead plates and indeed between any two plates, and then discontinued from the source of the current and their terminals again connected through a voltameter, you will observe a deflection. It was first thought that this secondary current was due to electricity actually charged on the plates in a manner similar to the alleged charge on a condenser, but it was soon discovered that it was due to the substances (gases or oxides as the case might be) derived from the original chemical decomposition.

From 1801 to 1859, the subject was studied by the most eminent chemists and physicists of their time, viz: Ritter, Grove, Oersted, Faraday, Becquerel, and many others.

In 1859, Gaston Planté, who made the most exhaustive researches in secondary batteries, constructed a secondary pile which is really the parent of all modern accumulators. A number of attempts have been made since that time to store the electrical energy of a dynamo, the most notable of which are those of Messrs. Thomson and Houston, in 1879, who patented and afterwards exhibited in this hall a gravity form of the Daniell cell, in which the zinc was reduced from its solution and the copper re-dissolved by the action of charging the cell from a dynamo or other source of electricity. During the last ten years, Chas. F. Brush, of electric light fame, to whom has finally been awarded (in the highest Court of Appeal) the priority of invention of the modern type of accumulator, M. Faure and a host of minor inventors have occupied the field with their respective inventions.

The Planté Battery.—The original Planté battery consisted of plates of lead on which the active material had been produced by electrical disintegration; that is to say, from the oxidizing action of the current alternately on each plate until a portion of the lead plate had been destroyed as lead, or in popular language, had become rusted. The formation of a Planté battery was a very tedious operation, often requiring months before it had been carried sufficiently far to enable the operator to get any useful return from a given charge. The reason for this is clear, from the fact that on charging two lead plates for the first time the oxygen liberated at the positive pole makes a thin film of peroxide of lead, but peroxide is a conductor, and then as the gas is liberated from the surface of the plate the peroxide when once formed really protects the body of the plate from further oxidation during that particular charge. If now we reverse the current and pass it through long enough to reduce all the peroxide to spongy lead, which is exceedingly porous through the loss of oxygen, the spongy mass allows of a freer circulation of the electrolyte, and new surfaces are exposed on an additional reversal whereby more peroxide of lead is formed. It is manifest that if this operation were to be continued long enough, the lead plates would be entirely

converted into peroxide of lead, or spongy lead, and the maximum efficiency and minimum of weight of material would be obtained. But right here is the main difficulty with the Planté battery. As it approaches a useful stage in formation from the amount of active material produced compared with the total weight of the plate, its life is suddenly cut off by reason of there being no longer a sufficient amount of metallic conductor for the current to properly distribute itself with respect to the electrolytic reactions that must take place in recharging. For you must understand that when a battery has been discharged, the peroxide of lead has been converted into sulphate of lead, which is a non-conductor, and the consequence of any attempt to force the current through such a substance will be to detach it from its metallic backing and render it useless, for the active material must be in electrical and mechanical contact with the conducting support in order to be available. If the current does not pass through the active matter to the electrolyte, the active matter is not oxidized or reduced, as the action of the electrolytic gases only takes place at the point of contact. Nascent oxygen and hydrogen are necessary for oxidation and reduction. As the plates are gradually peroxidized in formation the metallic portion which acts as the conductor continues to diminish, the internal resistance to increase until the battery will positively refuse to work, or, what is equivalent to the same thing, the current is all used up in the electrolysis of the electrolyte without accomplishing any useful result. This, then, as I have said, is the radical defect of the Planté battery, and even though it had no others would render its commercial use impossible. If the Planté principle were true, it would only be necessary to have a mass of spongy lead and a plate of peroxide and we would have an ideal battery because this is the logical result to be aimed at. But, unfortunately, for the reason I have explained in regard to the sulphating, it is impossible to accomplish.

We are, therefore, compelled to accept one of two alternatives, either to make a thick plate with low efficiency per pound and comparatively long life, or a thin plate with high

efficiency, but short life. Is there not a central point between the two which we might choose combining the two desirable features—long life with high efficiency? Most assuredly, but before this point is reached the other disadvantages of the Planté system make their presence felt, and a careful study of the problem must convince any intelligent electrical engineer that there can be no future for the Planté battery in competition with the Brush-Faure type.

There have been many forms of the Planté battery, and among the best of these was that adopted by the Brush Company, many years ago, and which was afterwards used, I believe, to light a train on the Pennsylvania Railroad. It consisted of a heavy plate of lead with laminations or leaves extending vertically at right angles to the plane of the plate. These batteries, I understand, worked fairly well, but their ampère hour capacity per pound of battery was so small that in order to accomplish a comparatively small result, for example, operating a few sixteen candle-power lamps, an enormous weight of battery was required, and the expense and trouble in hauling such a weight for so insignificant a return, together with other difficulties, led to its abandonment by the Pennsylvania Railroad after a fair and impartial trial.

The Brush-Faure Battery.—We come now to the consideration of the Brush-Faure type of battery, the type that has finally replaced all others, and notwithstanding the fact that the subject has been studied during the last ten years by some of the brightest chemists and physicists in this country and abroad, nothing has been discovered to change or replace the methods employed by them. I do not mean to say that no improvements have been made in the methods of manufacture, but the broad principle of the mechanical application or combination of the active material with the conducting support plate, which has been awarded to Brush in this country, has not been improved upon in any way, either by further discoveries or by a totally new departure in another direction.

As this type, therefore, seems to be the one that will alone survive in the struggle for existence, let us examine

its construction a little more minutely. In the earlier forms of this battery plain sheets of lead were used and the active material or oxide of lead was simply plastered over the surface of the plate, thin sheets of felt or other insulating material were placed between the plates and then the whole number were rolled into a cylindrical form or bound together with various clamping devices. This was merely a makeshift, and at first sight to any one familiar with a Planté battery would not only have not seemed like an improvement but really a step backward. But the principle was right, and it only required a little mechanical skill to insure far better results than Planté ever obtained. Brush patented every conceivable form of plate for retaining the active material, including what is also known as the "grid" form, or Swan type; and Volkmar, Sellon and Swan, on the other side, obtained patents for various improvements over Faure. But the manufacture has finally narrowed down to one form or type, and that is the grid. Of course, there are dozens of other types of grid, some of them very ingenious, but there is really no good reason for their existence. No form of grid could be devised which gives such an enormous conducting surface for a minimum weight of material except the honeycomb or hexagonal form, and this for some mechanical reasons is impracticable to make. There is also no form that exposes such a large superficial area of active material, and in which it is brought into such close electrical contact with the conductor or grid. Such a form, moreover, admits of the nicest adjustment of the proportion of grid to active matter, for if it is desirable to lessen the weight of the grid (and thereby increase the active material) for a given thickness of plate, this can be readily done by making the cross bars farther apart or thinner in cross sectional area. The alleged advantages of the so-called thick plate batteries have not yet been fully demonstrated. A thick plate of the grid form can just as readily be made as a thin one, but merely to make a plate thicker in order to make it stronger mechanically is not sufficient. The question is not how thick or how thin should a plate be, but how thick or thin it should be in order to do the greatest amount

of work. Every one knows that a thick plate will last longer than a thin one, but how much work will it do measured in watt hours, compared with a thin one, and for the same cost?

The next question we will consider is that of filling the grids with the active material. This is a very important point in the process of manufacture, and if not properly done will give trouble subsequently in operating the battery, and diminish its life. The method usually employed by the various manufacturers of storage batteries is to mix the oxide of lead with a dilute solution of sulphuric acid until it becomes a thick paste, and then to plaster this material in the grid with a trowel, carefully removing the excess from the surface of the plate. This is rather an expensive method of filling, as it requires a man, who is more or less skilled, to properly fill the plates, and such a man can only fill from seventy to 100 plates per day. Mr. Henry G. Morris has invented an ingenious machine for doing this work, whereby two boys with one machine can fill 1,500 plates per day. The machine is an hydraulic press to which is attached a circular table with radiating arms supporting iron blocks or stands on which the grids are placed, and the grids after being filled with the proper amount of active material, are passed successively under the press and subjected to a hydraulic pressure, varying from 1,000 to 2,000 pounds per square inch. The oxides are previously mixed with a dilute solution of sulphuric acid, not in such quantities, however, as to make a paste, but sufficient to partially sulphate them, and get them into a condition very similar in physical properties to ordinary moulding sand. The oxides, after being mixed with the acid solution, are sifted through a fine sieve, in order to break up all lumps, and are then heaped upon the grid, in the form of a powder, slightly rubbed into the interstices of the grid, the excess removed with a straight edge, and then compressed. In this manner plates can be filled uniformly and accurately at a minimum cost without the personal equation which is such a large factor in hand filled plates. Another important feature in filling is the condition the active material will assume after formation.

If the oxides are mixed with a considerable quantity of dilute acid, or sufficient to make them into a paste, and then applied to the grid, a considerable proportion of their bulk is water which dries out and leaves the mass in a loose condition in the holes or spaces of the grid. There is also a further loss in volume in the negative plate after formation, owing to the reduction of the litharge, or PbO, to spongy lead. This loss amounts to eight per cent. by weight, and in some plates made in this way, that I have recently seen, which had been used for traction work, the shrinkage had become so great that when the plates were removed from the acid and allowed to dry you could actually see, by holding them up, a line of light between the active material and the grid, and in order to render them useful again they will have to be repasted. Of course, this increased the internal resistance, and diminished the efficiency of the battery. As it is the active material that does the work in a battery, this density and better electrical and mechanical contact with the grid as a result of the compression, is a valuable feature of this method of filling. In fact, the life of a battery, other things equal, is limited by the time required to wash away the peroxide of lead in the positive plates. Peroxide of lead formed in this way is non-metallic and finely divided, and when freshly formed after a full charge has very little more consistency than a hard mud. It is only after it has become sulphated by discharging the battery that it gets hard and even stony when removed from the acid and dried.

Spongy lead, on the contrary, is, of course, metallic and the particles are comparatively closely knit together and tough and horn-like.

This brings us to the process of formation, or charging as it would be more proper to call it, in the case of a Brush battery as opposed to that of a Planté. After the plates are filled they are assembled together, alternately, positive and negative, into groups of as many each as it is desirable to handle, and after temporary mounting, are placed in an acid bath and charged with a current from one-half to one ampère per pound of element. The operation is purely one of elec-

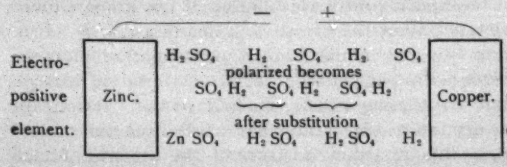
trolysis. Oxygen is liberated at the positive plate and hydrogen at the negative. The oxygen acts on the red lead and sulphate of lead in the positive plates and converts them into peroxide, the hydrogen acts on the litharge and sulphate of the negative plates, reducing them to spongy lead. It requires a continuous charge of 900 ampère hours to completely reduce the negative plates in a "17 S" accumulator, or (say) 100 ampère hours per negative plate, or, 200 ampère hours per pound of active material or litharge, each plate containing about one-half pound. Practically this is a very interesting statement aside from the battery question, as it is an exact measure of the amount of electrical power required to reduce a pound of lead from its oxide and as the E.M.F. is about 2·5 volts the amount of power required is 500 watt hours or less than three-fourths of an electrical horse-power per pound of lead. After formation the plates are washed and dried and are then permanently mounted into the various types that we have here this evening.

Having described briefly the method employed in manufacturing a battery, we will now consider the question of operating a battery, and the reactions, etc., that take place in charging and discharging, and finally the applications to which they can be applied.

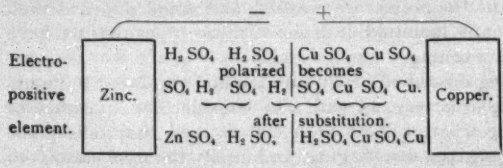
It is hardly necessary for me to say that there is no actual storage of electricity in an accumulator; it is simply a convenient reservoir for storing the active ingredients necessary to generate a current of electricity. In fact, a charged battery becomes a primary battery, and the current derived from it is based on identical principles. The reaction which takes place when a battery is discharged can best be examined by referring first to a primary battery with a simple zinc-copper couple.

When a positive element like zinc is opposed to a negative element in dilute sulphuric acid, the following reaction occurs. On uniting the poles of the battery the molecules of H_2SO_4 become polarized, then the acid radical is turned towards the electro-positive element Zn and the basic ion towards the electro-negative element. Substitution then

takes place, and the sulphuric radical unites with the zinc to form a molecule of zinc sulphate, and an interchange of molecules then takes place along the line until the negative pole is reached, where hydrogen (two atoms) is liberated. This can be expressed graphically as follows:

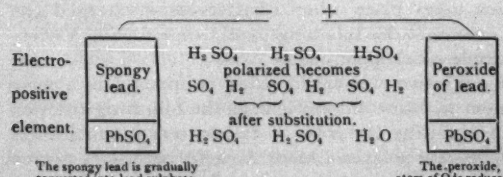


Let it be supposed that at the electro-negative element, where the hydrogen is liberated, there is some substance that it can combine with or displace, then the following action takes place as in the ordinary Daniell cell:



The first action is the polarization of the molecules; the second, a general substitution all along the line, forming zinc sulphate at one end and depositing metallic copper at the other, one atom of copper being equivalent to two atoms of hydrogen displaced in the former reaction.

With the knowledge thus gained we can now study the discharge of a secondary battery.



The spongy lead is gradually converted into lead sulphate.

The peroxide, giving up one atom of O is reduced to protoxide which in presence of sulphuric acid is immediately converted into lead sulphate.

In this case the polarization occurs as above and the substitution then takes place, forming a sulphate of lead on one pole, and liberated hydrogen at the other. But here there is a substance, peroxide of lead, which yields up its oxygen to the liberated hydrogen and forms a molecule of water. The oxide of lead formed by the reduction of the peroxide is, of course, instantly changed into sulphate of lead by the sulphuric acid. The action of the discharge is, therefore, to gradually sulphate both poles of the battery. Sulphate of lead, being insoluble in sulphuric acid and water, remains in the grids or support plates in place of lead and peroxide. The reaction in charging is more complex, and is not so well understood, but the final result is to leave the plates in the same condition as mentioned above before discharging. The conditions in charging, moreover, are not identical with those of discharging. It has been found that when a current from an external source is passed through two platinum plates in acid, polarization results, and oxygen is liberated at one pole and hydrogen at the other. When a secondary battery is completely discharged the plates are practically similar; that is, they are both lead plates, containing sulphate of lead. Hence, there is no difference of potential and no current results from connecting their terminals. It is, therefore, immaterial (so far as the chemical action is concerned) to which pole is connected the positive pole of the external source, which may be either a battery or a dynamo. In either case the plates now act in a manner similar to the platinum plates mentioned above, and oxygen is liberated at the pole through which the current enters and hydrogen at the opposite pole. In fact, the operation of charging is really one of simple electrolysis.

The reaction which takes place at the positive pole is

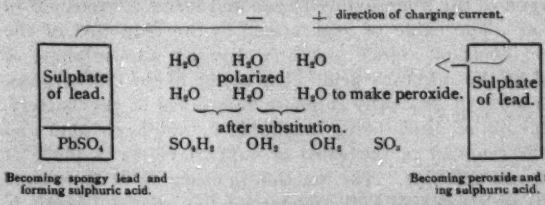
$$PbSO_4 + O + H_2O = PbO_2 + H_2SO_4$$

and at the negative pole

$$PbSO_4 + H_2 = Pb + H_2SO_4.$$

In other words, peroxide of lead is re-formed from the sulphate at one pole, spongy lead at the other and sulphuric

acid at both poles. The battery is then once more in condition to perform work. The reaction can be represented graphically as follows, the current flowing in the opposite direction from that shown above:



That sulphuric acid is formed at both poles is proved by the specific gravity of the solution after charging. What has been done, then, when a secondary battery is discharged, is to burn lead to sulphate. The amount of energy produced thereby can be determined quantitatively.

Having described the chemical reactions taking place within the cell, what I now desire to call your particular attention to and to show you, is, that a pound of zinc burned to oxide of zinc or a pound of lead burned on a grate, or in the open air to oxide of lead produces exactly the same mechanical equivalent in foot-pounds as a pound of zinc, or lead consumed in a battery and developing current produces. This fact, which was long since deduced from the doctrine of the conservation of energy, is of the highest importance to be borne in mind, if we desire to get a correct idea of electricity. It is amazing that with this doctrine of the correlation of forces, and the further fact that the intrinsic or specific energy of a pound of any substance is precisely the same whether set free as heat or electricity, that there should still be such a confusion and failure in the average mind to grasp the meaning or idea of what electricity is. There is no more mystery about electricity than there is about heat or any other force, except the one great and incomprehensible mystery of its existence, and it can as truly be defined as a "mode of motion" as heat. If a piece of zinc be placed into dilute sulphuric acid a violent

action immediately takes place with the evolution of hydrogen gas, and the generation of a definite amount of heat, or in another case if the temperature be raised sufficiently high, the zinc will combine with the oxygen in the air and burn to oxide with the generation of a definite amount of heat for every unit of weight. If, however, we connect this piece of zinc with a copper wire, the end of which is also placed into the acid, the wire becomes endowed with the extraordinary properties which are produced by what we call an electric current, and as this phenomenon appears the generation of heat in the acid disappears. In other words, the potential energy charged on the atoms or molecules of zinc is, in the act of combination of the zinc with the sulphuric radical, set free and manifests itself either as heat or electricity.

1 gram Zn to Zn O,	=	1,300	calories.
1,300 × 3·06 (foot-pounds per calorie)	=	3,978	foot-pounds.
3,978 × 454 (grams per pound),	=	1,806,000	foot-pounds per pound of Zn.
1 coulomb,	=	·000330	grams Zn.
1 gram,	=	3,000	coulombs.
454 grams or 1 pound,	=	1,362,000	coulombs.
1,362,000 × ·74 (foot-pounds per coulomb,	=	1,000,000	foot-pounds.
Zn giving 2 equivalents,	=	2,000,000	foot-pounds per pound of Zn.

Unit E.M.F. or one volt, acting through unit resistance, one ohm, gives a current of one ampère, which continued for one second yields the unit of energy, one coulomb, equal to $\frac{1}{746}$ horse-power and since one horse-power equals 550 foot-pounds of work per second, one coulomb equals $\frac{550}{746} = 0{\cdot}7373$ foot-pound in a second. Electric current is measured by the amount of chemical work performed in a given time. Taking hydrogen as the unit, the amounts of the other elements set free by the same electric current are proportional to the atomic weights of the various elements compared with hydrogen as one, due allowance being made for the valency af the element under consideration. The amount of current which will release ·00001022 gram (or 0·000158 grains) of hydrogen per second is the unit of current or the ampère, and an ampère under unit conditions;

that is, at one volt and through one ohm resistance for one second, is called a coulomb. This is the real tangible part, so to speak, of electricity, and is exactly analogous to a heat unit which all engineers thoroughly understand. In fact, a coulomb is equal to 0·24 calorie or 0·74 foot-pound. It is this knowledge, therefore, that enables us to calculate theoretically the total amount of energy that can be derived from a given weight of any substance consumed electrically. That is to say, every act of chemical combination is attended with a loss of potential energy; that is, the energy becomes kinetic, is set free and manifests itself as heat, electricity, or motion. The converse of this proposition is likewise true, that every act of chemical decomposition requires a supply of energy exactly equal to the amount lost or set free in making the substance which is to be decomposed, and this energy disappears as potential energy charged on the atoms or molecules of the substances decomposed. The energy derived from the substitution of lead for hydrogen in sulphuric acid in the above reactions, is the source of the E.M.F. of the battery, and the amount or actual weight of lead consumed represents the current which will be produced, measured in coulombs.

Now the atomic weight of lead is 207. Lead being a dyad, its electrical equivalent is 103·5 and $103{\cdot}5 \times {\cdot}00001022 = {\cdot}001058$ gram. In other words, the consumption of ·001058 gram of lead in a battery furnishes a current of electricity of one ampère for one second or one coulomb, or one coulomb will deposit ·001058 gram of lead. One gram of lead, therefore, equals 944 coulombs ($1 \div .001058 = 944$). In an accumulator of the "17 S" type containing nine negative and eight positive plates, there is nearly five pounds of spongy lead, and since five pounds equals 2,273 grams, $2273 \times 944 = 2{,}145{,}712$ coulombs. Dividing by 3,600 (number of seconds in an hour), we have 586 (say 600 ampère hours at one volt pressure), as the theoretical capacity of the accumulator, or about eight-tenths of a horse-power hour. This would be equivalent to 300 ampère hours at two volts, the normal working pressure of a lead peroxide battery, and corresponds almost exactly with the amount obtained from the

total discharge of a pile. It is, however, only rated as a 150 ampère hour pile, because in practice a total discharge is never accomplished.

This is a matter of the first importance as it enables us at once, without a practical test, to form a correct judgment as to the truth of claims that may be made as to the capacity and efficiency of any given battery.

Having now examined, briefly, the mode of operation of a battery, we come finally to consider its application for various purposes.

The first use to which storage batteries were applied was electric lighting. When the modern type of storage battery was first introduced it was hailed as the evolution of the great problem of electrical distribution, and we were informed by many, who should have known better, that our houses and offices would soon be lighted by batteries which would be carted around and delivered in much the same fashion as ice and coal is to-day, but the fact is that a storage battery is a very expensive thing for the amount of its storage capacity, and even after the investment is made the expense of maintaining the battery in first-class working order is still very considerable, amounting probably to twenty-five per cent. per annum of its first cost. For example, a fifty-light plant costs about $1,000, and $250 per annum to maintain, irrespective of the cost of charging and generating machinery. You can readily understand, therefore, why you are not all enjoying the luxury of electric lights in your houses at the present time. At the same time, a storage battery is so essential for a complete isolated electric light installation, that its use is growing every day, and with its growth the first cost will undoubtedly diminish, and where properly employed, the cost of maintenance be reduced to a minimum, perhaps as low as five per cent. per annum.

Let us see how we estimate for equipping a fifty-light plant. In the first place, the voltage of the lamps must be considered. If a 100-volt lamp, fifty accumulators must be used in series, as each gives but two volts. One hundred-volt sixteen candle-power lamps require about 0·6 ampères each, and

(*Salom*)

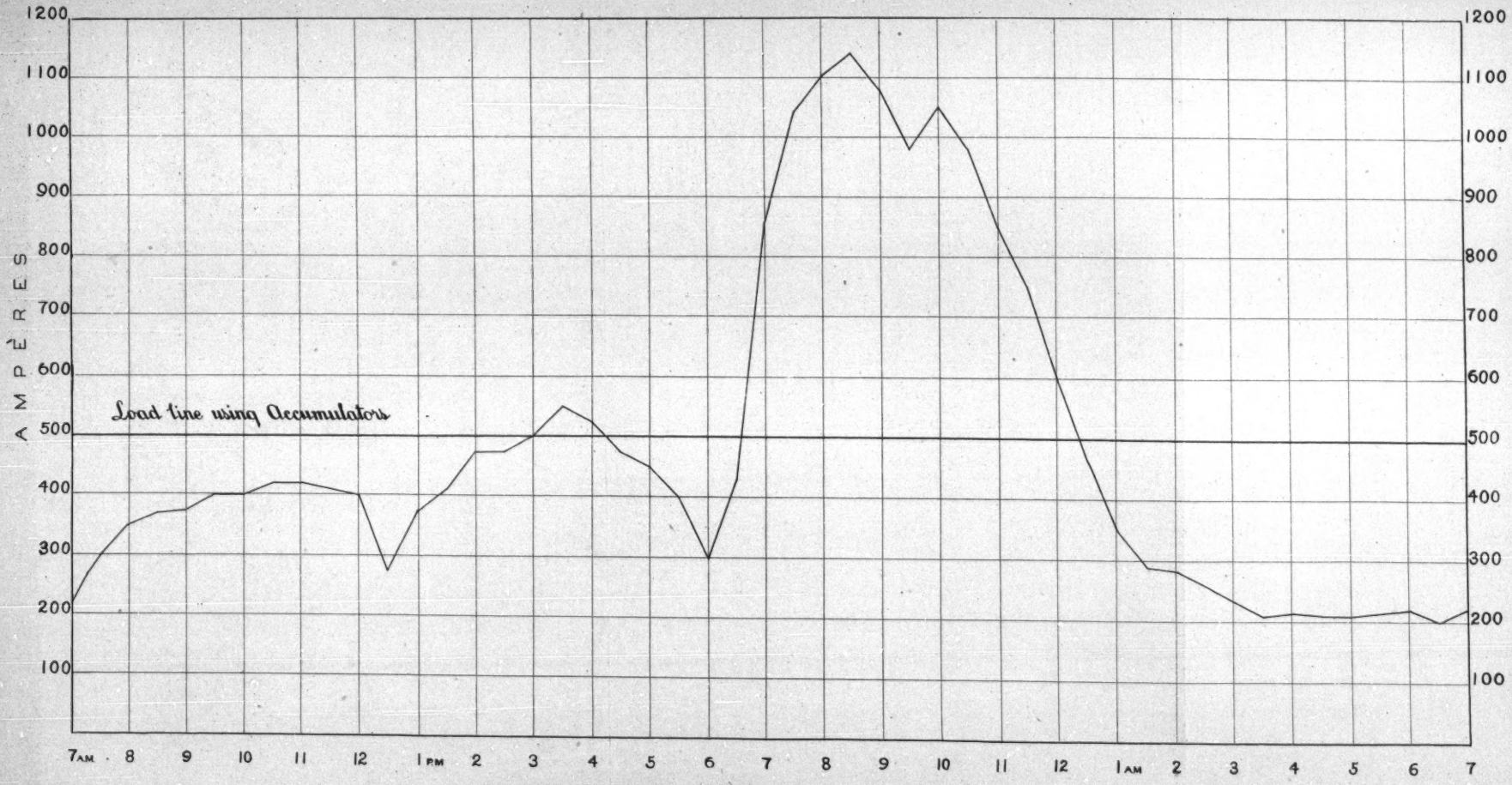


DIAGRAM OF LOAD ~ ATLANTIC CITY ELECTRIC LIGHT STATION.

fifty would, therefore, require thirty ampères. We must, therefore, select a type of accumulator large enough to stand such a high rate of discharge, for a comparative long period of time, without injury. We use for this purpose type "15 I." Of course, very much larger currents can be obtained from such a battery, but it is only done at the expense of the life of the pile.

You can readily understand how it may be very economical to run a batttery in connection with a direct lighting plant. Suppose, for example, there is a 1,000-light plant to be installed, and the number of hours in the day during which the entire load, or maximum load, is used is only three, then if this plant of 100 horse-power must be kept in operation to feed fifty or 100 lights for the balance of the twenty-four hours, it can only be done at a great sacrifice of economy. In such a case a storage battery, properly installed, instead of being a source of expense, is really an economy and renders the cost of operating the plant considerably less.

It is also absolutely indispensable for isolated domestic lighting apart from a central station.

The second important use to which storage batteries have been successively applied is in connection with central station lighting. Very little or anything has been done in this country in this direction up to the present time, although arrangements are now being perfected that will insure within a short time a successful demonstration of the value of storage batteries in central station lighting. The conditions under which the central station plants are now operated are such as to render it impossible to effect economical distributions. This may be illustrated by the accompanying diagram, showing the load curve of a central station.

It will be seen from an inspection of the same, that the maximum load only lasts for a few hours per day, yet in order to provide for this load the generating machinery must be sufficient to supply the same, even if only employed for an hour. This entails a much larger investment than is really absolutely necessary, and an additional number

of small dynamos to take care of the load during the hours of minimum demand. Whereas, by the use of storage batteries, larger units of power may be installed and worked at their maximum output and efficiency during the entire twenty-four hours.

The even line shows how the curve would appear in the same central station by employing storage batteries.

In other words, by employing generating machinery with a maximum load of 500 ampères for the twenty-four hours, using the surplus power for charging the batteries, the power plant, in this case, could be cut down at least one-half.

Storage battery installations may be made in such cases with a capacity of from 3,000 to 5,000 ampères for from three to ten hours, as may be desired. By such means the load curve can be reduced to almost a straight line, which would mean, of course, the maximum efficiency of a plant at the minimum cost of operating. There are many such central station plants in Europe successfully operated by the Tudor battery, which is a special type of the Brush battery, but the limits of a lecture will not permit of any detailed description of the same.

The third important use to which storage batteries may be applied is in mechanical traction, for the propulsion of street cars and other vehicles. I have already given you, on former occasions, many of the particulars connected with this work in this and other countries, and notwithstanding the apparently unfortunate results connected with the attempts to make street-car traction commercially successful, I desire to place myself on record as predicting that ultimately storage battery traction will entirely supersede the trolley for street-car service. Of course, for suburban and country roads the trolley will occupy its legitimate field. For other purposes of traction, such as the movement of carriages, wagons, etc., the storage battery can alone be used. One of the most successful applications of storage batteries is the running of electric launches. This is really an ideal method of running a small boat or pleasure launch, and the fact that this method has been

selected above all others, after a most severe competitive trial, to run all the boats on the lagoons at the World's Columbian Exposition in Chicago, this year, is the most striking evidence of the degree of perfection obtained in this branch of the industry.

Finally storage batteries are successfully used for an infinite number of minor purposes, of which it will only be necessary to enumerate a few of the more striking examples, viz: The operation of phonographs, sewing machines, dental engines, dental and surgical instruments, telegraph and telephone lines, call bells, small motors and lamps, electro-chemical and metallurgical operations, electric welding, and a host of others.

From the above it must be evident to the dullest observer that storage batteries are destined to play an ever increasing and important part in the development of electrical science, and, therefore, a careful and conscientious study of the principles underlying their construction and application is worthy of the efforts of the best electrical talent, apart from the intense interest the operation of the batteries themselves possess, being connected, as it were, with the very genesis of electricity itself.

COPPER MINING IN THE UNITED STATES.

By C. Kirchhoff, Editor of *The Iron Age.*

[*A lecture delivered before the Franklin Institute, February 20, 1893.*]

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Americans have grown so thoroughly accustomed to claiming preëminence in industrial achievements, that little comment is now created when one after the other branch of production pushes forward into the first rank, so far as quantity of output is concerned.

The utilization of our great mineral resources has pro-

gressed so rapidly in the past decade that we accept, in a matter-of-fact manner, attainments over which we might have been wildly excited ten or fifteen years ago.

We are now the greatest producers of iron ore, pig iron and steel. We are far ahead of any country in our output of lead; have poured enormous quantities annually of precious metals into the coffers or the world. Probably before the end of this century we shall raise more mineral fuel than Great Britain, and outstrip all other nations in the manufacture of spelter.

We have thus taken the first step towards industrial preeminence in nearly all branches of mining and metallurgy, but it is really only in one in which we have progressed *beyond* that point, and that is, in the production of copper. I take it that, commercially, our *first* aim must be to cover our own rapidly increasing requirements; the *second* must be to capture as large a share as we can of the markets of the world, consistent with reasonable husbanding of our resources.

Naturally, at first, the products of our mines go out in the cruder form, and it is in that stage of our development that we are now in the copper trade. Our manifest destiny is, however, to do more and more the work of converting the raw article into the finished product for the consumer, and make the world pay us tribute not alone for our vast resources, but also for energy, skill and taste as manufacturers and for enterprise and ingenuity as traders. It will be a grand struggle, in which those qualities which have won for us the contest for our own home markets will assure to us the victory in distant fields.

Permit me to sketch for you this evening, in rough outline, the main features of the development in one relatively small branch of our mining industry. Let me make a brief inventory of our resources; let me show you how one by one our principal districts rushed into prominence, carrying our country not alone to the rank of the greatest copper producer of the world, but making it also one of the principal contributors to and by far the most influential factor in the world's markets.

The first copper mine worked in the United States appears to have been the Simsbury, near Granby, Conn., a company having been formed in 1709. Ten years later the Schuyler mine, near Belleville, N. J., was discovered, and with a number of others in that vicinity was worked for a number of years. In fact, the first steam pumping plant erected in this country was probably that used by Josiah Hornblower, in 1753, at the Belleville mine. Pennsylvania entered the ranks with the Gap mine, in Lancaster County, in 1732. It does not appear, however, that any work of moment was done until the middle of the present century. The Ely mine, in Vermont, which had been discovered in 1820, began to be worked only in 1850, and from then on till 1880 was a factor. The Ducktown group of mines in Tennessee, now being re-opened, were discovered in 1846, but produced heavily only a few years later. Late in the fifties and early in the sixties, California shipped relatively heavy quantities, but dropped back to an insignificant place after the exhaustion of the richer surface ores. While they contributed important quantities at that time to the country's store of the metal, the mines of the Atlantic and the Pacific coasts soon dropped to a minor position before the rising glory of the Lake Superior district.

The existence of copper in the native state on Lake Superior was mentioned as early as 1659 or 1660, in the *Relations des Jesuites*, and Father Claude Allouez described a stray mass in 1666. In 1771, Alexander Henry organized a company in England to mine copper on the Ontonagon River, Charles Townshend, Duke of Gloucester, and others, being incorporators. Failing to find copper in place, Henry renewed operations in 1772 on Michipicóten Island, on the north shore of Lake Superior, but only to score another failure. For nearly three-quarters of a century the copper resources of Lake Superior failed to attract attention, until in 1841, Dr. Houghton gave the world the first authentic and scientific account of the geology of the Keweenaw series and of the occurrence of the native copper. The first mine, the Cliff, was opened in 1844, and in the next year Lake Superior copper first made its appearance in the markets of

this country, which it was destined to dominate for so many years, particularly when the Calumet and Hecla, which first appeared as a producer in 1867, began to pour forth its metal.

That position the Lake mines held until, in 1881, when the Union Pacific road opened the necessary transportation facilities for the Butte District of Montana, and the Southern Pacific completed its road into Arizona and New Mexico. Since then there have been years of almost bitter struggle for supremacy between the Montana and the Michigan districts particularly, and the output has increased at a tremendous rate.

Leaving out of account a number of scattered sources of supply, furnishing considerable metal in the aggregate, but individually unimportant, the producing mines of this country may be classed in three groups, each possessing its special features, each enjoying some advantages and suffering under some drawbacks. The development of each of them has been attended with characteristically American disregard of precedent in older countries, with its attendant record of disastrous failures, but also with that bold and ingenious adaptation of original means to an end, which is the wonder of Europeans in so many American industrial enterprises. In the light of subsequent events, the commercial policy and the technical management of many prominent American copper mining undertakings may easily be criticised with much show of wisdom. But in its broader lines, considering the commercial and technical limitations, the development of the industry is one of which Americans may justly be very proud.

The three groups referred to are the Lake Superior, the Butte, Montana and the Arizona; the first working an ore containing the copper in native form; the second yielding sulphuret ores containing some silver; and the third depending chiefly upon oxidized ores. Permit me to take them up in turn, prefacing with the general remark that, generally speaking, copper as a mineral is very much in evidence. Its oxides and carbonates possess a brilliant coloring, so that in regions like our Rocky Mountain terri-

tories prospectors have been quick to report their finds. Up to the present time, there are no sections of the country promising important new developments, except possibly the Seven Devils district in Idaho.

THE LAKE SUPERIOR MINES.

In the Lake Superior district, the deposits first to attract attention were what is known as the mass mines, which worked either on the transverse fissure veins of Keweenaw County towards the point of the promontory, or on the interbedded veins of the Ontonagon country, towards the base of the promontory. The early famous mines belonged to this class, among them the Cliff, the Minnesota, the Central, and others. The copper is found in great sheets or masses, at times many hundreds of tons in weight, the Minnesota having a record of one mass of 500 tons, while a series of related masses in the Central yielded 1,200 tons of native copper. The cutting up of these great bodies of tough, metallic copper was a very laborious and costly undertaking. With greater depth the veins appeared to become leaner, and practically to-day the famous old mass mines have ceased to play any part.

With the exception of the Central, all the important mines of the district are now working one of two classes of deposits interbedded in a lava in what is locally known as trap, the *amygdaloid* beds and the *conglomerate* beds. They dip westerly towards Lake Superior at an angle varying between 30° and 50°. In them a part of the original mineral constituents have been displaced by native copper. The principal difference, from a practical point of view, between the two classes of beds, is that the amygdaloids are usually softer, and can therefore be more cheaply worked, while the conglomerate rock is much harder, and therefore requires a richer ore to pay.

The amygdaloid mines were first opened in 1851, the Copper Falls being the pioneer. To-day the most important concerns working on amygdaloid deposits are the Quincy, the Franklin and the Atlantic. It was not until 1864 that the Albany and Boston Company attempted to work a con-

glomerate bed, followed in 1865 by the most famous of the Lake mines, the Calumet and Hecla. The story is told that the attention of a camping party was called to a pig rooting in a shallow excavation, which proved to be a pit dug by a prehistoric miner. The mine thus revealed has given to its stockholders, on $100,000, nearly $40,000,000 in dividends, with more to come.

The stories of the great masses of native copper found in the Lake Superior district have created the impression that the yield of the ore is very great. As a matter of fact, the rock is really very poor. Thus the Atlantic, an amygdaloid mine, has contrived to live, and pay moderate dividends, on a yield of only 0·60 to 0·70 per cent. of copper, while the Quincy, the richest of this class, can claim only two per cent. from sorted rock. The Calumet and Hecla from its richest ground takes only four and one-half per cent. ore, the average being near three and one-fourth per cent. It is true that at times very rich places are encountered. I myself, in a tour of the mine, visited one face where the men working on contract were thoroughly disgusted because they had started a number of drill holes, only to abandon them because they were being forced to punch their way through solid metal.

The persistency of both the amygdaloid and conglomerate beds in depth and in metal-bearing, has been pretty thoroughly proven by a number of deep shafts. The Quincy is down to its 4,000-foot level, on the incline, while the Calumet and Hecla is little less than that. It was proven, too, in a most striking manner, by the bold undertaking of the Tamarack Company, conceived by John Daniell and his associates in Boston. Early in 1882, a vertical shaft was started, when the lower drifts of the neighboring Calumet and Hecla were far above the level at which the Tamarack shaft was expected to pierce the lode. In 1885, at a depth of 2,270 feet, the bed was struck, carrying an excellent percentage of copper. The mine paid from the start, and has contributed to its stockholders, thus far, over $3,000,000. Its success and the manifest advantages of vertical shafts over inclines for deep work, have led to

further work in this direction, so that there are now sunk, or sinking, seven shafts, of which the deepest will reach the lode in 5,000 feet, or nearly a mile.

In the mining operations proper there is nothing particularly novel or striking in the Lake Superior district. The use of rock-drilling machinery and high explosives has made it possible to break rock at a low cost, and has, it might almost be said, created the great operations of the present day. In some of the mines, a good deal of poor rock is sorted out and stowed away underground. In others, notably in the great mines on the conglomerate, the whole of the bed is taken out, which calls for an enormous amount of timbering.

It was in the subsequent working of the copper rock that American facility in meeting unusual conditions manifested itself. The problem of extracting native metal from rock had not presented itself elsewhere. It was the introduction of the Ball steam stamp—a clever adaptation, to the special purpose, of the Nasmyth hammer—which solved the question. Its later history has curiously illustrated, too, how dangerous a guide long-established practice may be. For nearly a generation the mortars were placed on a carefully prepared foundation of spring timbers, the idea being that a certain amount of elasticity was essential. A few years since, it occurred to one of the stamp-mill superintendents that it might be wiser to make a solid foundation. The result showed a marked increase in efficiency, and now spring timbers are rapidly going out of use.

The rock, as it comes from the mine, is crushed in the steam stamp mills, and is then jigged, the finer material being washed on buddles. I shall be able to show you photographs of some of this machinery in dealing with one of the leading Montana mines.

One or two photographs will best serve to give you an idea of the topography of the copper country. I shall couple with it photographs of some of the great Calumet and Hecla machinery, which has a special interest for Philadelphians, because nearly every one of these giants was built in your city.

THE MONTANA MINES.

Butte, Mont., first attracted attention as a silver camp, and the story goes that its greatest producer, the Anaconda, was first opened in the hope that it would yield the bright metal. Marcus Daly, the discoverer and one of the principal owners of the property, assures me that there is no foundation for this tale. Still, the silver mines were famous long before the copper deposits were worked. The veins, which have raised Butte to the rank of the greatest mining camp of the country, are enclosed within a rectangle, having a length of two and one-half miles and a width of about one mile. At its eastern end the mines are argentiferous, copper predominating in the west. A very large number of veins course through the granite hill, and more are being gradually discovered under the wash at its base. At the surface the copper contents were relatively low, while the silver was present in greater quantity. But at the water line, at a depth of 50 to 150 feet, the vein filling changed somewhat suddenly in character, being heavily charged with copper sulphurets, copper glance and peacock copper predominating. A good many of the veins are large, their thickness rising to over 100 feet, although the average does not probably go above seven or eight feet. The great mass of the ore is not rich, running from four to ten per cent. of copper, but enormous quantities of very rich ore, carrying from twenty-five to thirty-five per cent. of copper have been mined. In fact, the greatest shock which the copper markets of the world sustained was that growing out of the sudden shipments to England, by the Anaconda mine in Butte, of many thousands of tons of rich ore.

While there is a large number of individual mines, the copper mining and reduction interests of Butte are in relatively few hands, the prominent companies being the Anaconda, Boston and Montana, Butte and Boston, Parrott, and the Butte Reduction Works.

The development of the camp soon proved that its future must rest rather on the successful utilization, commercially and technically, of the abundant stores of low grade ores,

than upon the extraction of occasional bunches of rich ground. The mining presents little difficulty except that growing out of the excavation of great openings in such mines as the Anaconda and St. Lawrence, where rock filling has now become the main reliance. Some trouble is also encountered in the sliding of the ground, due to intense mining operations in a relatively small territory.

A good deal of experimenting, however, grew out of the efforts to dress the ores to a higher percentage. The German system of concentration by crushing, screening and jigging was developed in some plants, while others, notably the Anaconda, adopted the Lake Superior methods and appliances.

The earlier plants were located at Butte, but the Anaconda was the first to undertake the treatment of the ores at another locality. It was followed later by the next largest concern, the Boston and Montana, which built a great concentrating and smelting plant at Great Falls, Montana, where water power in abundance, at low cost, was available.

The ore after it is concentrated goes to the smelting works. First, it is roasted, to drive off a part of the sulphur, either in open stalls, which have enveloped Butte in a cloud of smoke, against which there was a vigorous popular protest, or in reverberatory or rotary calcining furnaces.

The roasted ore is either smelted in reverberatory furnaces or in blast furnaces, the product being a sulphide of copper and iron, or matte, carrying from fifty to sixty-five per cent. of copper. Some of the photographs which I will show you will give you an idea of the character of this plant.

The great bulk of the product of the Montana mines is being shipped to Eastern refiners and works in England, as matte.

All of the Butte copper ores carry varying quantities of silver. In some cases the silver is of so much importance that copper is really only a carrier for the more precious metal, accompanying it through all the operations until it is finally separated. The Williams smelter concentrates the silver in a high grade copper matte, which is shipped to

Denver to the parent company, the Boston and Colorado Company, where the two metals are separated by Pearce's methods and the Ziervogel process.

A somewhat different procedure is followed at the other works, and promises to become the characteristic method of Butte. The Parrott Company was the first to adopt the Manhes method of bessemerizing copper matte for the elimination of the sulphur and the production of a "blister" copper, or high grade metallic copper. The Anaconda and the Boston and Montana have followed the example thus set, the former in an experimental plant, and the latter in their new Great Falls works, in which the smelting department with its tilting reverberatories and arrangement of Bessemer plant clearly shows the influence of American steel practice due to the efforts of Henry Aiken, of Pittsburgh, who acted as consulting engineer.

The product of the bessemerizing is a metallic copper which is cast into slabs. These carry from fifty to 150 ounces of silver to the ton. This is separated by the electrolytic method. Until lately this has been done either by works in the East identified with the Montana mines, as in the case of the Bridgeport Copper Company, which is affiliated with the Parrot, or by independent copper refiners, like the Orford, Baltimore, Chicago, and others at home, or the Vivians and other smelters abroad. Lately, however, the Anaconda has been operating an experimental plant, and the Boston and Montana is building a large refinery at Great Falls. When the plans of American producers are fully developed, the exports of matte will probably cease, and the work of turning out the ingot copper and wire bars will be entirely performed in this country.

The electrolytic refining plants are surrounded with a good deal of mystery at the present time and access to them is not easily obtained.

The argentiferous copper is cast into anodes, which are suspended, covered with bagging, in vats containing an acidulated solution of sulphate of copper. The cathodes are copper sheets. By the passage through the vats of an electric current, the copper is dissolved from the anodes and

deposited on the cathodes, the silver remaining behind in the bags as a mud, with what impurities the copper may contain. The current at Anaconda is one of 950 ampères and fifty to sixty volts. The deposited copper must be remelted, refined, and cast into bars or ingots.

THE ARIZONA MINES.

The third important group of copper mines is that of Arizona, whose resources became available when in 1881 the railroads began to enter the territory. What distance from supplies and markets means is well illustrated by the fact that the Longfellow, which began work late in the seventies, had to cart its copper 700 miles to the nearest railroad station in Kansas. The high cost of fire-brick, $1 a piece delivered, led to the introduction of the water-jacketed furnace, then untried in copper smelting, the first jackets being cast of copper on the spot. Since then their use has become general in dealing with oxidized ores in the blast furnace. Nearly all of Arizona copper comes from three districts, the Bisbee, the Clifton and the Globe. A good deal of mining excitement attended the early development and wild stories of the richness of the ores were utilized to float all sorts of schemes. Now the production comes from a very small number of companies operating on a large scale. The characteristic feature of the ores of the three leading Arizona districts is that the ores are oxides and carbonates, from which copper, ninety-five to ninety-seven per cent. fine, can be obtained in the one operation of smelting in the blast furnace. This copper is of exceptional purity, and is shipped to refiners on the Atlantic seaboard, to be converted into ingots and bars. In all the three districts, the ore occurs in or adjacent to carboniferous limestones, the decomposition due to the infiltration of surface waters having extended to the depths thus far reached, although bodies of unaltered sulphuret ores are occasionally met with. The mines have opened large bodies of rich ores, but on the whole the average copper contents is not as high as is usually stated. The furnace yield of sorted ore ranges from about eight per cent. at the Bisbee mines, to twelve

and fifteen per cent. at some of the others, the closeness of the sorting depending upon cost of fuel, etc.

Besides the metal produced by the three principal districts, quite a considerable quantity of copper is obtained from scattered sources. Principal among these, not easily traceable, is that which is obtained as an incidental product of the lead smelting operations in different parts of the Rocky Mountain regions. A somewhat curious circumstance is the discovery, in the sulphuret deposits of some of the deeper Leadville mines, of notable quantities of copper. A large quantity of the metal is also smelted from imported and domestic pyrites used in the manufacture of sulphuric acid.

Each of the three great districts possesses advantages of some importance. The lake still retains its preëminence in the quality of its product, followed closely, however, by the Arizona product.

The bessemerizing, coupled with the electrolytic method, has, however, made it possible to produce from impure raw material a high quality metal, so that the absence of arsenic, sulphur and other substances in the ore mined has not the great advantage which it once was.

On the question of cost the Census has established figures which still hold good. The average yield of the Michigan ore treated was 1·797 per cent., the cost of mining being 8·55 cents per pound. Montana on a 7·002 per cent. ore shows a 3·27 cents mining cost, while Arizona follows with 10·079 per cent. ore and a 3·66 cents mining cost.

The Lake mines yield an ore, the crushing and washing of which furnishes a high grade product. These operations cost 0·59 cent per pound, and the refining and marketing adds about 1·60 cents per pound more, making the total 10·74 cents per pound.

The Census report shows that the cost of concentrating and smelting in Montana was 6·16 cents per pound. The cost of shipment and of refining probably carries this to about 11 cents per pound. Later returns for silver and better equipment probably reduce this cost.

The Arizona mines add 4·01 cents for concentrating and

smelting to the mining cost, making 7·67 cents for the blister at furnace. The cost of transportation carries this near 10 cents per pound at New York.

CONCLUSION.

During the periods of adversity and trial which the copper industry of the United States has undergone during the past decade, its three great districts have proven their ability to live in competition with all the producers of the world, in spite of relatively high wages and great distance from market. In fact, the broad statement may be made that the larger and richer mines can pay comfortable dividends to their stockholders when the great German, Spanish, Australian and Japanese mines are finding it difficult to make ends meet. The probability is that additional economies in mining, milling, smelting, refining and marketing will more than compensate for the naturally advancing cost due to deeper mining. In fact, it seems probable that at no distant day deposits hitherto considered too poor may be profitably operated.

We are undoubtedly making tremendous inroads annually into the reserves of our known mines, and during the past few years no finds of consequence have held out the hope that there will be new claimants to fame. Still, there is a good deal of ground yet unprospected in the Lake Superior district, and great new discoveries are still among the possibilities. In the Rocky Mountains there are known large deposits as yet inaccessible, which promise to fill any coming gaps. For the near future the position of the United States as the grandest copper producer is assured. We shall remain the leaders for some time to come.

On Light and other High Frequency Phenomena.*

By Nikola Tesla.

[*Continued from p. 279.*]

If a wire or filament be immersed in a homogeneous medium, all the heating is due to true conduction current, but if it be enclosed in an exhausted vessel the conditions are entirely different. Here the gas begins to act and the heating effect of the conduction current, as is shown in many experiments, may be very small compared with that of the bombardment. This is especially the case if the circuit is not closed and the potentials of course very high. Suppose a fine filament enclosed in an exhausted vessel be connected with one of its ends to the terminal of a high tension coil and with its other end to a large insulated plate. Though the circuit is not closed, the filament, as I have before shown, is brought to incandescence. If the frequency and potential be comparatively low, the filament is heated by the current passing *through it*. If the frequency and potential, and principally the latter, be increased, the insulated plate need be but very small, or may be done away with entirely; still the filament will become incandescent, practically all the heating being then due to the bombardment. A practical way of combining both the effects of conduction current and bombardment is illustrated in *Fig. 24*, in which an ordinary lamp is shown provided with a very thin filament which has one of the ends of the latter connected to a shade serving the purpose of the insulated plate, and the other end to the terminal of a high tension source. It should not be thought that only rarefied gas is an important factor in the heating of a conductor by varying currents, but gas at ordinary pressure may

* A lecture delivered before the Franklin Institute, at Philadelphia, February 24, 1893, and before the National Electric Light Association, at St. Louis, March 1, 1893.

become important, if the potential difference and frequency of the currents is excessive. On this subject I have already stated, that when a conductor is fused by a stroke of lightning, the current through it may be exceedingly small, not even sufficient to heat the conductor perceptibly, were the latter immersed in a homogeneous medium.

From the preceding it is clear that when a conductor of high resistance is connected to the terminals of a source of high frequency currents of high potential, there may occur

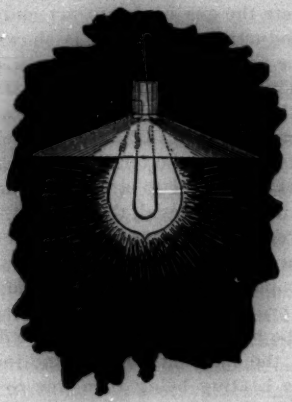


FIG. 24.—Utilizing the heating effect of conduction current and bombardment.

FIG. 25.—Illustrating lateral diffusion.

considerable dissipation of energy, principally on the ends of the conductor in consequence of the action of the gas surrounding the conductor. Owing to this, the current through a section of the conductor at a point midway between its ends may be much smaller than through a section near the ends. Furthermore, the current passes principally through the outer portions of the conductor, but this effect is to be distinguished from the skin effect as ordinarily interpreted, for the latter would or should occur also in a continuous incompressible medium. If a great many incandescent

lamps are connected in series to a source of such currents, the lamps at the ends may burn brightly, whereas those in the middle may remain entirely dark. This is due principally to bombardment, as before stated. But even if the currents be steady, provided the difference of potential is very great, the lamps at the ends will burn more brightly than those in the middle. In such case there is no rhythmical bombardment and the result is produced entirely by leakage. This leakage, or dissipation into space, when the tension is high, is considerable when incandescent lamps are used, and still more considerable with arcs, for the latter act like flames. Generally, of course, the dissipation is much smaller with steady, than with varying currents.

I have contrived an experiment which illustrates in an interesting manner the effect of lateral diffusion. If a very long tube be attached to the terminal of a high frequency coil, the luminosity is greatest near the terminal and falls off gradually towards the remote end. This is more marked if the tube is narrow.

A small tube about one-half inch in diameter and twelve inches long, *Fig. 25*, has one of its ends drawn out into a fine fibre *f* nearly three feet long. The tube is placed in a brass socket *T*, which can be screwed on the terminal T_1 of the induction coil. The discharge passing through the tube first illuminates the bottom of the same, which is of comparatively large section; but through the long glass fibre the discharge cannot pass. But gradually the rarefied gas inside becomes warmed and more conducting and the discharge spreads into the glass fibre. This spreading is so slow, that it may take half a minute or more until the discharge has worked through up to the top of the glass fibre, then presenting the appearance of a strongly luminous thin thread. By adjusting the potential at the terminal, the light may be made to travel upwards at any speed. Once, however, the glass fibre is heated the discharge breaks through its entire length instantly. The interesting point to be noted is that, the higher the frequency of the currents, or, in other words, the greater relatively the lateral dissipation, the slower will be the rate at which the light be made to

propagate through the fibre. This experiment is best performed with a highly exhausted and freshly made tube. When the tube has been used for some time the experiment often fails. It is possible that the gradual and slow impairment of the vacuum is the cause. This slow propagation of the discharge through a very narrow glass tube corresponds exactly to the propagation of heat through a bar warmed at one end. The more quickly the heat is carried away laterally the longer will be the time required for the heat to warm the remote end. When the current of a low frequency coil is passed through the fibre from end to end, then the lateral dissipation is small and the discharge instantly breaks through almost without exception.

After these experiments and observations which have shown the importance of the discontinuity, or atomic structure, of the medium, and which will serve to explain, in a measure at least, the nature of the four kinds of light-effects producible with these currents, I may now give you an illustration of these effects. For the sake of interest I may do this in a manner which to many of you might be novel. You have seen before that we may now convey the electric vibration to a body by means of a single wire or conductor of any kind. Since the human frame is conducting I may convey the vibration through my body.

First, as in some previous experiments, I connect my body with one of the terminals of a high-tension transformer and take in my hand an exhausted bulb which contains a small carbon button mounted upon a platinum wire leading to the outside of the bulb, and the button is rendered incandescent as soon as the transformer is set to work (*Fig. 26*). I may place a conducting shade on the bulb which serves to intensify the action, but this is not necessary. Nor is it required that the button should be in conducting connection with the hand through a wire leading through the glass, for sufficient energy may be transmitted through the glass itself, by inductive action, to render the button incandescent.

Next I take a highly exhausted bulb containing a strongly phosphorescent body, above which is mounted a small plate

of aluminum on a platinum wire leading to the outside, and the currents flowing through my body excite intense phos

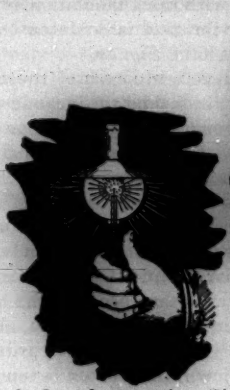


FIG. 26.—Incandescence of a solid.

FIG. 27.—Phosphorescence.

FIG. 28.—Incandescence or phosphorescence of rarefied gas.

FIG. 29.—Luminosity of gas at ordinary pressure.

Illustrating four kinds of light effects produced by high frequency currents of high potential.

phorescence in the bulb, *Fig. 27*. Next, again I take in my hand a simple exhausted tube, and in the same manner the

gas inside the tube is rendered highly incandescent, or phosphorescent, *Fig. 28*. Finally, I may take in my hand a wire, whether it be bare, or covered with thick insulation, is quite immaterial, when the electric vibration is so intense as to cover the wire with a luminous film, *Fig. 29*.

A few words must now be devoted to each of these phenomena. In the first place, I will consider the incandescence of a button, or of a solid in general, and dwell upon some facts which apply equally to all these phenomena. It was pointed out before that when a thin conductor, such as a lamp filament, for instance, is connected with one of its ends to the terminal of a transformer of high tension, the filament is brought to incandescence partly by a conduction current and partly by bombardment. The shorter and thicker the filament the more important becomes the latter, and finally, reducing the filament to a mere button, all the heating must practically be attributed to the bombardment. So in the experiment before shown, the button is rendered incandescent by the rhythmical impact of freely movable small bodies in the bulb. These bodies may be the molecules of the residual gas, particles of dust, or lumps torn from the electrode; whatever they are, it is certain that the heating of the button is essentially connected with the pressure of such freely movable particles, or of atomic matter in general, in the bulb. The heating is the more intense the greater the number of impacts per second and the greater the energy of each impact. Yet the button would be heated also if it were connected to a source of a steady potential. In such a case electricity would be carried away from the button by the freely movable carriers or particles flying about, and the quantity of electricity thus carried away might be sufficient to bring the button to incandescence by its passage through the latter. But the bombardment could not be of great importance in such case. For this reason it would require a comparatively very great supply of energy to the button to maintain it at incandescence with a steady potential. The higher the frequency of the electric impulses, the more economically can the button be maintained at incandescence. One of

the chief reasons why this is so, is, I believe, that with impulses of very high frequency there is less exchange of the freely movable carriers around the electrode, and this means, that in the bulb the heated matter is confined more rigorously to the neighborhood of the button. If a double bulb, as illustrated in *Fig. 30*, be made, comprising a large globe *B* and a small one *b*, each containing as usual a filament *f*, mounted on a platinum wire *w* and w_1, it is found, that if the filaments *f f* be exactly alike, it requires less energy to keep the filament in the globe *b* at a certain degree of incandescence, than that in the large globe *B*. This is due to the confinement of the movable particles around the button. In this case, it is also ascertained, that the filament in the small globe *b* is less deteriorated when maintained a

FIG. 30.—Showing the effect of confining the gas around the electrode.

certain length of time at incandescence. This is a necessary consequence of the fact that the gas in the small bulb becomes strongly heated and, therefore, a very good conductor, and less work is then performed on the button, since the bombardment becomes less intense as the conductivity of the gas increases. In this construction, of course, the small bulb becomes very hot and when it reaches an elevated temperature the convection and radiation on the outside increase. On another occasion, I have shown bulbs in which this drawback was largely avoided. In these instances a very small bulb, containing a refractory button, was mounted in a large globe and the space between the walls of both was highly exhausted. The outer large globe remained comparatively cool in such

constructions. When the large globe was on the pump and the vacuum between the walls maintained permanent by the continuous action of the pump, the outer globe would remain quite cold, while the button in the small bulb was kept at incandescence. But when the seal was made, and the button in the small bulb was maintained incandescent some length of time, the large globe also, would become warmed. From this I conjectured that if vacuous space (as Professor Dewar finds) cannot convey heat, it is so merely in virtue of our rapid motion through space, or, generally speaking, by the motion of the medium relatively to us, for a permanent condition could not be maintained without the medium being constantly renewed. A vacuum cannot,

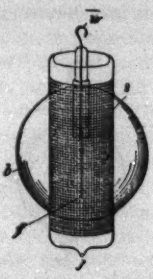


FIG. 31.—Showing the inefficiency of a metal screen.

according to all evidence, be permanently maintained around a hot body.

In these constructions, before mentioned, the small bulb inside would, at least in the first stages, prevent all bombardment against the outer, large globe. It occurred to me then to ascertain how a metal sieve would behave in this respect, and several bulbs, as illustrated in *Fig. 31*, were prepared for this purpose. In a globe *b*, was mounted a thin filament *f* (or button) upon a platinum wire *w* passing through a glass stem, and leading to the outside of the globe. The filament *f* was surrounded by a metal sieve *s*. It was found in experiments with such bulbs that a sieve with wide meshes apparently did not in the slightest degree affect

the bombardment against the globe *b*. When the vacuum was high, the shadow of the sieve was clearly projected against the globe, and the latter would get hot in a short while. In some bulbs the sieve *s* was connected to a platinum wire sealed in the glass. When this wire was connected to the other terminal of the induction coil (the E.M.F. being kept low in this case), or to an insulated plate, the bombardment against the outer globe *b* was diminished. By taking a sieve with fine meshes, the bombardment against the globe *b* was always diminished, but even then, if the exhaustion was carried very far, and when the potential of the transformer was very high, the globe *b* would be bombarded and heated quickly, though no shadow of the sieve was visible owing to the smallness of the meshes. But a glass tube, or other continuous body, mounted so as to surround the filament, did entirely cut off the bombardment, and for a while the outer globe *b* would remain perfectly cold. Of course, when the glass tube was sufficiently heated the bombardment against the outer globe could be noted at once. The experiments with these bulbs seemed to show that the speeds of the projected molecules, or particles, must be considerable (though quite insignificant when compared with that of light), otherwise it would be difficult to understand how they could traverse a fine metal sieve without being affected, unless it were found that such small particles, or atoms, cannot be acted upon directly at measurable distances. In regard to the speed of the projected atoms, Lord Kelvin has recently estimated it at about one kilometre a second, or thereabouts, in an ordinary Crookes bulb. As the potentials obtainable with a disruptive discharge coil are much higher than with ordinary coils, the speeds must, of course, be much greater when the bulbs are lighted from such a coil. Assuming the speed to be as high as five kilometres and uniform through the whole trajectory, as it should be in a very highly exhausted vessel, then if the alternate electrifications of the electrode would be of a frequency of 5,000,000, the greatest distance a particle could get away from the electrode would be one millimetre, and if it could be acted upon directly at that distance, the

exchange of electrode matter, or of the atoms, would be very slow, and there would be practically no bombardment against the bulb. This at least should be so, if the action of an electrode upon the atoms of the residual gas would be such as upon electrified bodies which we can perceive. A hot body enclosed in an exhausted bulb produces always atomic bombardment, but a hot body has no definite rhythm, for its molecules perform vibrations of all kinds.

If a bulb containing a button or filament, be exhausted as high as is possible with the greatest care and by the use of the best artifices, it is often observed that the discharge cannot, at first, break through, but after some time, probably in consequence of some changes within the bulb, the discharge finally passes through and the button is rendered incandescent. In fact, it appears that the higher the degree of exhaustion the easier is the incandescence produced. There seems to be no other cause to which the incandescence might be attributed in such case except to the bombardment, or similar action, of the residual gas, or of particles of matter in general. But if the bulb be exhausted with the greatest care can these play an important part? Assume the vacuum in the bulb to be tolerably perfect the great interest then centres in the question: Is the medium which pervades all space continuous or atomic? If atomic then the heating of a conducting button or filament in an exhausted vessel might be due largely to ether bombardment, and then the heating of a conductor in general through which currents of high frequency or high potential are passed must be modified by the behavior of such medium; then also the skin effect, the apparent increase of the ohmic resistance, etc., admit partially, at least, of a different explanation.

[*To be concluded.*]

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting held Tuesday, October 17, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 17, 1893.

DR. D. K. TUTTLE, Vice-President, in the chair.

Dr. Wahl proposed the name of Mr. L. F. Kebler, chemist to Smith, Kline & French Company, manufacturing chemists, 305 Cherry Street, Philadelphia. The name was referred to the Committee on Admissions and Mr. Kebler was duly elected.

A letter from Miss Lizette A. Fisher to Dr. Wahl, announced the death of our fellow-member, Mr. R. A. Fisher, on October 6th. Dr. Tuttle appointed Mr. H. Pemberton, Jr., to prepare a suitable minute of the sad event.

Mr. Boyer suggested that such lectures of the Institute's general course, as were of special interest to chemists be made a part of the proceedings of the Section. Dr. Wahl stated that such a plan would be highly desirable, but its execution would be attended with serious expense to the Section, such expense being incidental to publication.

Dr. Wahl remarked, further on, the desirability of making the selection of lecturers on chemical topics, a duty of the Section. The president and others concurred in the views expressed by Dr. Wahl.

Dr. Hooker then read a paper "On the Azines of the Lapachol Group," and followed it with another on "The Change from Ortho- to Para- and from Para- to Ortho-Quinones." The papers were listened to with much interest, and were afterwards informally discussed by the author and Dr. Hall, Prof. Smith and Dr. Keiser. Beautifully crystallized specimens of the substances treated of were submitted for inspection.

A paper entitled "Experiments on Slag Cements," by Mr. R. W. Mahon was, in the absence of the author, read by title and referred for publication.

Adjourned.

WM. C. DAY, *Secretary.*

THE DETERMINATION OF PHOSPHORIC ACID BY THE TITRATION OF THE YELLOW PRECIPITATE WITH STANDARD ALKALI.

BY HENRY PEMBERTON, JR.

[*Read at the stated meeting of the Chemical Section, held Sept. 19, 1893.*]

In the year 1882, I described a process for determining phosphoric acid, volumetrically, by ammonium molybdate, on the principle of Wildenstein's sulphuric acid determination, or of Gay Lussac's silver method. An *aqueous* solution of ammonium molybdate is run into the solution of the phosphate until no further precipitate is formed.

But it is not of this process that I now have to speak. It is referred to here, in order to draw attention to the concluding paragraph of the paper, as follows:

"I have obtained very sharp and accurate results by determining the amount of yellow precipitate (formed as above, after thorough washing), by means of a standard solution of caustic alkali, using litmus as an indicator; a description of which I hope to present in a future paper. I mention it here simply to place the fact on record." (*Journ. Frank. Inst.*, **113**, 193; *Chem. News*, **46**, 7.)

At that time I did a considerable amount of work upon the last-mentioned process, with very satisfactory results. A study was made of the conditions most favorable to obtaining a phospho-molybdate precipitate of constant composition, using solutions of di-sodic hydric phosphate of known strength, and also a solution of apatite, the determinations being checked by standard methods.

Before the process was in shape for publication, however, my attention was called to work of an entirely different nature, and no description of the method was published other than that embodied in the above-quoted paragraph.

Since that time several chemists have described processes based upon the same principle.

E. Thilo, in the analysis of Thomas slag (*Chem. Ztg.*, **11**, 193), dissolves the yellow precipitate in standard ammonia, and titrates back with acid, using litmus as an indicator.

Franz Hundeshagen (*Zeit. Anal. Chem.*, **28**, 171) uses standard sodium hydrate in excess, and titrates back with nitric acid, using phenolphthalein as an indicator.

C. E. Manby (*Jour. Anal. and Appd. Chem.*, **6**, 82) determines the phosphorus in steel, iron and iron ones, by dissolving the yellow precipitate in ammonia, acidifying with nitric acid, evaporating to dryness, and heating gently to expel nitric acid and ammonium nitrate. He then titrates, using the same solution and indicator as Hundeshagen employs.

James O. Handy (*Jour. Anal. and Appd. Chem.*, **6**, 204) avoids the evaporation and heating and titrates directly as Thilo and Hundeshagen do, using standard soda and phenolphthalein. M. Rothberg and W. A. Auchinvole (*Jour. Anal. and Appd. Chem.*, **6**, 243) also describe the same process.

Although it is now eleven years since I drew attention to this process, its advantages are so great that any information touching it, in addition to that furnished by the foregoing chemists, may be of interest. It far surpasses in quickness the process described by me (on the Gay Lussac or Wildenstein principle) and at the same time lacks nothing in accuracy. In most of the papers of the above-mentioned chemists, the process is applied to the determination of phosphorus in small quantities, as it occurs, for instance, in iron, steel or ores. During the past year, I have had occasion to apply it to the examination of a number of phosphate rocks, as well as of strong solutions of phosphoric acid, containing over fifty per cent. P_2O_5 and the method has been used continuously during that time. I am indebted to Mr. Edwin Harris, who had charge of most of the laboratory work of the factory, for many of the figures given below. It was seldom that two tests of the same material differed more than 0·1 per cent. in P_2O_5 even when the total P_2O_5 present amounted to as much as forty per cent. to fifty per cent. of the substance analyzed.

The following solutions are used:

Ammonium Molybdate.—Ninety grams of the crystals are dissolved (in a large beaker) in somewhat less than one litre of water. This is allowed to settle, overnight, and the clear liquor decanted into a litre flask. The small quantity of insoluble molybdic acid, always present, is dissolved in a little ammonia and added to the main solution. Should the molybdate be found to contain traces of P_2O_5, a few decigrams of magnesium sulphate are added, ammonia being added to faint alkalinity. The whole is then made up to one litre. It is this *aqueous* solution that is used, *no nitric acid whatever being employed.* Each cubic centimetre precipitates three milligrams of P_2O_5.

The *ammonium nitrate* solution is simply a saturated aqueous solution of the salt. Distilled water is poured into the bottle of crystals in quantity *in*sufficient to dissolve them all. Even in cold weather, ten cubic centimetres of this solution is amply sufficient for each test.

The *nitric acid*, used for acidifying the solution of the phosphate, has a specific gravity of 1·4, or thereabouts.

The *standard potassium hydrate* solution is of such strength that 1 cc. = 1 mgr. P_2O_5. One hundred cubic centimetres of it will neutralize 32·65 cubic centimetres of normal acid. It can be made from normal potassium hydrate (that has been freed from all carbonate, by barium hydrate), by diluting 326·5 cubic centimetres to one litre. But its strength is best determined empirically by a direct test upon a phosphate solution of known strength, precipitating with ammonic molybdate and making the analysis as described below, all carbonate of potassium having first been removed by barium hydrate.

The standard acid has the same strength, volume for volume, as the potassium hydrate, and can be made by diluting 326·5 cubic centimetres of normal acid to one litre. In testing it against the alkali, phenolphthalein (and not methyl orange) should be used.

The indicator can be either litmus, rosolic acid, or phenolphthalein. I have used the latter almost exclusively, as it has been shown, by J. H. Long (*Am. Chem. Jour.*, **11**, 84), that

titrations with this indicator in the presence of ammonium salts are perfectly reliable if the amount of the ammonium salt present is not excessive, if the solution is cold, and if the phenolphthalein is used in sufficient quantity. One gram of the phenolphthalein is, accordingly, dissolved in 100 cubic centimetres of sixty per cent. alcohol, and at least 0·5 cubic centimetres of this solution is used for each titration. The washing of the ammonium phospho-molybdate is done by water. (Isbert and Stutzer, *Zeit. Anal. Chem.*, **26**, 584.) It may be of interest to quote from their results, since it is by some chemists thought necessary to wash with a neutral or acid solution of an ammonium salt. In all tests, as made by them, twenty-five cubic centimetres of the sodium phosphate solution were precipitated by ammonium molybdate and the phosphoric acid determined therefrom, as magnesium pyrophosphate in the usual manner.

When the yellow precipitate was washed with ammonium nitrate solution, there was obtained:

(1) 0·1943 gram P_2O_5 in 50 cc.
(2) 0·1948 gram P_2O_5 in 50 cc.

When washed with *water*, there was found:

(3) 0·1947 gram P_2O_5 in 50 cc.
(4) 0·1942 gram P_2O_5 in 50 cc.

In order to establish the fact more certainly, the precipitate was washed with unusually large quantities of water:

	cc. of water used in washing.	*P_2O_5 found.*
(5)	300	0·1947 in 50 cc.
(6)	400	0·1944 in 50 cc.
(7)	500	0·1948 in 50 cc.
(8)	1,000	0·1940 in 50 cc.

There is, accordingly, no danger of loss in washing the yellow precipitate with water.

The following is the method of performing the analysis:

One gram of the phosphate is dissolved in nitric acid, an excess of which can be used with impunity, and the solution filtered into a 250 cubic centimetre flask and made up to the mark. The solution can even be poured into the flask without filtering, since the presence of a little insoluble

matter does not interfere in the least with the titration. Moreover, since most phosphate rocks seldom contain over ten per cent. of insoluble matter, and as this has the specific gravity of at least 2, it occupies a volume of about 0·05 cubic centimetre, an amount so small that it may be neglected. (For instance, even in the case of a phosphate rock containing forty per cent. P_2O_5, the error is only 0·008 per cent. P_2O_5.)

After the clear solution has been poured off, it is well to treat the sand, etc., at the bottom of the beaker, with a cubic centimetre or so of hydrochloric acid, in the warmth, to insure complete solution.

It is not necessary to evaporate to dryness. Isbert and Stutzer have shown, in their paper, that when the yellow precipitate is washed with *water*, the soluble silica is removed, and that evaporation (to render the silica insoluble) is superfluous. Their results are corroborated by the test analysis that will be given below. In the event of its being desirable to remove silica by evaporation, for any purpose, the evaporation should be performed over a water-bath, or, if on an iron plate, with great care, since, otherwise, meta- or pyro-, phosphates are formed with results that are correspondingly low.

Twenty-five cubic centimetres of the solution (equal to 0·1 gram) are now taken for analysis. It may be thought, by some, that an analysis made upon so small a quantity of material as one decigram, and with a standard solution representing only one milligram per cubic centimetre, may be liable to errors that would not exist, when using larger quantities or stronger solutions. But it should be borne in mind that the accuracy of measurement with a twenty-five-cubic-centimetre pipette, is precisely the same, whether ten grams of the original substance are taken or only one gram. Any error in measuring with a pipette is, of course, entirely independent of the quantity in solution. In regard to the amount of material to be manipulated (filtered, washed, etc.) it will be remembered that the weight of the yellow precipitate is over twenty-eight times the weight of the P_2O_5 contained in it. Every milligram of

P_2O_5 is accordingly represented by more than twenty-eight milligrams of precipitate. The standard alkali, although representing only 0·001 gram per cubic centimetre is, in reality more than three times as strong as the decinormal solution generally employed. Of course, in the case of materials containing only ten to fifteen per cent. P_2O_5, as in fertilizers, two or three grams can be taken for analysis, if desired, instead of one gram.

Returning, therefore, to the method of the analysis, twenty-five cubic centimetres of the solution are measured out and delivered into a beaker holding not more than 100 to 125 cubic centimetres. A larger beaker requires unnecessary washing to remove the free acid in washing the yellow precipitate. The solution is neutralized with ammonia—until a precipitate just begins to form—and five cubic centimetres of nitric acid of specific gravity 1·4 added. Ten cubic centimetres of the ammonium nitrate solution are added, and the entire bulk of the solution made up to fifty to seventy-five cubic centimetres by adding water.

Heat is now applied and the solution brought to a full boil. It is then removed from the lamp, no more heat being applied and treated *at once*, with five cubic centimetres of the aqueous solution of ammonium molybdate, which is run into it from a five-cubic-centimetre volume pipette, the solution being stirred as the precipitate is added. The beaker is now allowed to rest quietly for about one minute, during which time the precipitate settles almost completely. The five-cubic-centimetre pipette is filled with the molybdate solution, and a part of its contents allowed to drop in, holding the beaker up to the light. If a formation of a yellow cloud takes place, it is at once perceptible, in which case the remainder of the pipettefull is run in, the solution stirred and allowed to settle. A third pipettefull is now added as before. Should it cause no further cloud, only about one-half of its contents is added, the remainder being run into the beaker into which the filtrate and washings from the yellow precipitate are to go. In the test analyses given below, it will be shown that even when *fifteen cubic centimetres in excess*, of the molybdate, were purposely used, over and above the

calculated amount, the results were accurate—no molybdic acid coming down with the yellow precipitate.

It is seldom that more than fifteen cubic centimetres in all (three five-cubic-centimetre pipettefulls) of the molybdate have to be added. Since each cubic centimetre precipitates three milligrams P_2O_5, fifteen cubic centimetres will precipitate forty-five milligrams P_2O_5. This is equivalent to forty-five per cent. on the 0·1 gram taken for analysis, and it is not often that any material to be examined contains over this percentage. In the analysis of materials rich in phosphoric acid, it is one of the embarrassing features of the usual process, in which the *nitric acid solution* of the molybdate is used, that, in the first place, large quantities of the precipitant have to be used (frequently several hundred cubic centimetres), and, in the second place, that the analyst is never certain that enough has been added to throw down all of the phosphoric acid. This necessitates frequent testings of small portions of the phosphate solution, or of the filtrate. There is another difficulty peculiar to the process as usually carried out, in all methods in which the determination is made directly upon the phospho-molybdate itself, in that much care must be observed to keep the solution at a certain temperature, since otherwise molybdic acid contaminates the precipitate and the analysis is rendered worthless. In the process herein described, using an *aqueous* solution of the molybdate, the point at which sufficient of the precipitant has been added is easily seen. No molybdic acid separates, because, in the first place, no great excess of molybdate is added; and because, in the second place, the solution is filtered immediately, or as soon as it has settled, which requires only a minute or two. The time required from the first addition of the molybdate to the beginning of the filtration is never over ten minutes, and is generally less. The filtrate and washings from the precipitate when treated with additional molybdate solution, give, on standing on a hot plate for an hour or so, a snow-white precipitate of molybdic acid, showing that all of the phosphoric acid has been precipitated. I have observed this hundreds of times.

A slight correction should be made to the statement made above in regard to fifteen cubic centimetres of the molybdate precipitating forty-five milligrams of P_2O_5. This is not strictly true, for the reason that a small quantity (something over one cubic centimetre) of the molybdate is required to neutralize the solvent action of the nitric acid. Therefore, in *very* high grade phosphates a fourth five cubic centimetre pipette full may be required.

The yellow precipitate is now filtered through a filter seven centimetres in diameter, decanting the clear solution only. This is repeated three or four times, washing down the sides of the beaker, stirring up the precipitate, and washing the filter and sides of the funnel above the filter each time. The precipitate is then transferred to the filter and washed there. When the precipitate is large it cannot be churned up by the wash water and cannot be washed down to the apex of the filter. This is generally the case when there is over ten or fifteen per cent. phosphoric acid present in the substance analyzed. In such an event, I am accustomed to wash the precipitate back into the beaker, and to fill the funnel with water above the level of the filter, doing this two or three times, then washing the precipitate back into the filter. It is not necessary to transfer to the filter the precipitate adhering to the sides of the beaker.

It goes without saying that during the washing no ammonia must be present in the atmosphere of the laboratory. Inasmuch as the beaker, funnel, filter and precipitate are small, the washing does not take long to perform. It requires, in fact, from ten to fifteen minutes, even when large precipitates (= thirty to forty per cent. P_2O_5) are handled. The precipitate and filter are now transferred together to the beaker. By pressure with the tip of the finger, upon the double fold of the filter, it is easily given a sideways motion and lifted out of the funnel without any danger of breakage, the precipitate being still within it. The alkali solution is run in until the precipitate has dissolved, at least twelve drops of the phenolphthalein (1 : 100) are then added, and the acid run in without delay until the pearly color disappears and the solution is colorless. The presence of the

filter paper does not interfere in the least. The reaction of the indicator is not so sharp as when only acid and alkali are used, but it is easy to tell with certainty the difference caused by one drop of either acid or alkali. After deducting the volume of acid used from that of the alkali, the remainder gives the percentage of P_2O_5 directly, each cubic centimetre being equal to one per cent. P_2O_5. Thus, if there are 28·3 cubic centimetres of alkali consumed, the material contains 28·3 per cent. P_2O_5 when one decigram is taken for analysis. From the time the twenty-five cubic centimetres are measured out until the result is obtained, from thirty to forty minutes are required.

I have applied this process to determinations of phosphoric acid in phosphates and fertilizers, and have had no experience in determining phosphorus in iron, steel, or iron ores. I am inclined to believe that in the presence of such large quantities of iron salts when using the *aqueous* solution of the molybdate it may be necessary to guard against contamination of the yellow precipitate by ferric hydrate, perhaps by using larger quantities of nitric acid than five cubic centimetres, and perhaps by washing the precipitate at first, with dilute nitric acid. It may also be the case that the yellow precipitate will form more slowly.

The following analytical experiments were made in order to test the process.

Several phosphate of soda solutions were used at first, the strength of which was only approximately known, as the aim was to see how closely two readings would agree; equal quantities of the phosphate being taken for each pair of tests.

A.

	cc.
(1) KHO with rosolic acid,	15·0
(2) KHO with rosolic acid,	15·15

B.

	cc.
(1) KHO rosolic acid,	30·5
(2) KHO rosolic acid,	30·5
(3) KHO phenolphthalein,	30·7

All titrations, after this, were made with phenolphthalein.

C.

	cc.
(1) KHO,	31·7
(2) KHO,	31·8

A KHO solution was now made of such strength that 1 cc. = 1 mgr. P_2O_5.

D.

	mgr.
(1) P_2O_5,	50·35
(2) P_2O_5,	50·55
(3) P_2O_5,	50·40

E.

	mgr.
(1) P_2O_5,	51·6
(2) P_2O_5,	51·55

F.

	mgr.
(1) P_2O_5,	51·05
(2) P_2O_5,	50·95

D, E and F were solutions used in standardizing.

Two different samples of Florida phosphate rock were examined.

I.

	Per Cent.
(1) P_2O_5,	= 29·68
(2) P_2O_5,	= 29·84

II.

(1) P_2O_5,	= 31·28
(2) P_2O_5,	= 31·34

The following were solutions of phosphoric acid:

I.

	Per Cent.
(1) P_2O_5,	= 46·78
(2) P_2O_5,	= 46·69

II.

(1) P_2O_5,	= 44·41
(2) P_2O_5,	= 44·63

III.

(1) P_2O_5,	= 48·95
(2) P_2O_5,	= 48·80

The effect of *an excess* of ammonium molybdate was tried. The soluble part of an acid phosphate was made up to a definite volume and fifty cubic centimetres taken for analysis. It was found to contain 8·28 per cent. P_2O_5. The

test was repeated, using fifteen cubic centimetres of the molybdate more than was used in the first trial. Result = 8·36 per cent. P_2O_5 equal to a difference of 0·08 per cent.

The following tests show that it is not necessary to remove silicic acid, by evaporating to dryness before precipitating with the ammonic molybdate.

A sample of Florida phosphate rock contained:

	Per Cent.
(1) P_2O_5 silica removed,	31·21
(2) P_2O_5 silica not removed,	31·21

Another sample of the same rock was also tried:

Silica removed:	*Per Cent.*
(1) P_2O_5,	= 30·5
(2) P_2O_5,	= 30·7
Average P_2O_5,	= 30·6

Silica not removed:	*Per Cent.*
(1) P_2O_5,	30·6
(2) P_2O_5,	30·7
Average P_2O_5,	30·65

When silica is not removed the filtrate from the yellow precipitate has a yellow tinge.

The relation between the P_2O_5 in the precipitate and the potassium hydrate was established by determining the strength of a solution of disodic hydric phosphate by precipitation as the ammonium-magnesium salt, and also by testing it by this titration process. The phosphate of soda solution was *weighed* (not measured), and the magnesia precipitate, after filtering, was dissolved and reprecipitated with ammonia. (Gooch, *Am. Chem. Jour.*, **1**, 405.) The results are given in Table I, the last column giving the amounts of P_2O_5 obtained on a basis of ten grams of the solution:

TABLE I.

	Weight of Na_2HPO_4 Solution. Grams.	*Weight of $Mg_2P_2O_7$ Obtained. Grams.*	*Equal to P_2O_5. Grams.*	*Grams P_2O_5 in 10 Grams of Solution.*
I,	75·824	1·2471	0·7956	0·10494
II,	101·167	1·6637	1·0614	0·10492
III,	101·622	1·6733	1·0675	0·10505
Average,				0·10497

Therefore, ten grams of the solution contain 0·10497 gram P_2O_5.

Weighed portions of the same solution were now precipitated with molybdate and the precipitate titrated with alkali. The results are given in Table II, the last column of which gives the number of cubic centimetres of alkali equivalent to ten grams of the solution. The indicator was phenolphthalein:

TABLE II.

	Weight of $Na_2H.PO_4$ Solution. Grams.	*Number of cc. of KHO Sol. Required.*	*= Number of cc. KHO Sol. Required for 10 Grams Solution.*
I,	7·4975	79·05	= 105·4
II,	7·8255	82·40	= 105·3
Average,			= 105·35

It follows, therefore, that 105·35 cubic centimetres alkali = 0·10497 gram P_2O_5, therefore,

(1) 100 cubic centimetres alkali = 99·64 milligrams P_2O_5.

The HCl solution was now titrated against the alkali, using phenolphthalein as the indicator. 99·00 cubic centimetres alkali were found to equal 99·05 cubic centimetres acid.

The HCl was then standardized against pure sodium carbonate.

(With methyl orange, cold:)

(*a*) 1·1291 grams Na_2CO_3 = 65·45 cubic centimetres HCl

(With phenolphthalein, boiling:)

(*b*) 1·1934 grams Na_2CO_3 = 69·2 cubic centimetres HCl

Therefore, 100 cubic centimetres =

(*a*) 1725· milligrams Na_2CO_3
(*b*) 1725· milligrams Na_2CO_3

Since 99·00 alkali = 99·05 acid, it follows that:

(2) 100 cubic centimetres alkali = 1726 milligrams Na_2CO_3

It has already been shown by (1) that 100 cubic centimetres alkali = 99·64 milligrams P_2O_5. Therefore, combin-

ing (1) and (2) we obtain 99·64 milligrams P_2O_5 = 1726· milligrams Na_2CO_3.

Dividing each by its molecular weight, we have:

for P_2O_5, ... $\frac{99·64}{142·06}$ = ·7014

for Na_2CO_3, ... $\frac{1726}{106·1}$ = 16·27

Therefore $P_2O_5 : Na_2CO_3 = 0·7014 : 16·27 = 1 : 23·2$.

In other words, 23·2 molecules of Na_2CO_3 are required to neutralize the yellow precipitate containing one molecule P_2O_5.

The above figures are based upon the following atomic weights:

Mg, ... = 24·3
O, ... = 16
P, ... = 31·03
Na, ... = 23·05
C, ... = 12

$Mg_2P_2O_7$ = 63·80 per cent. P_2O_5.

There is some uncertainty as to the correct atomic weight of magnesium. If Mg = 24 (instead of 24·3 as taken above) with $Mg_2P_2O_7$ = 63·98 per cent. P_2O_5 the ratio of Na_2CO_3 to P_2O_5 = 23·1 to 1 (instead of 23·2 to 1). It is difficult to obtain *absolutely* pure Na_2CO_3; any impurity in it will make the ratio of Na_2CO_3 to P_2O_5 too high.

Practically, therefore, twenty-three molecules of Na_2CO_3 are required for one molecule P_2O_5. This agrees with Hundeshagen's results.

I have never seen any explanation as to why twenty-three molecules of alkali are required to neutralize one molecule of the ammonium-phospho-molybdate. A discussion of the subject, therefore, may be of interest. Hundeshagen has shown (*loc. cit.*) that (neglecting any water of crystallization) the yellow precipitate, after thorough washing with water, has the following composition:

$$PO_4$$
$$12\ MoO_3$$
$$3\ NH_4$$

Or, doubling the formula, for the sake of clearness:

$$P_2O_5$$
$$24\ MoO_3$$
$$6\ NH_4$$

R. T. Thomson has shown in his researches on indicators (*Chem. News*, **47**, 127) that of the three hydrogen atoms in H_3PO_4 two must be saturated with alkali before the reaction with phenolphthalein will be neutral. The next drop of alkali after this causing the red color to appear. Writing the formula differently, $H_6P_2O_8$ must become $R_4H_2P_2O_8$ (R being the radical NH_4, or any alkali metal). Therefore, when the yellow precipitate is broken up by alkali, only four of the six molecules of NH_4 are required to form (with the P_2O_5 of the precipitate) a phosphate of ammonium that is neutral to the indicator. The remaining two molecules of NH_4 unite with one molecule of MoO_3, yielding also a salt that is of neutral reaction. This leaves twenty-three molecules of MoO_3, representing the "net available acidity" (if I may use the expression) of the ammonium-phosphomolybdate. These twenty-three molecules of MoO_3, of course require twenty-three molecules of Na_2CO_3 (or its equivalent of KHO) to form Na_2MoO_4. Q. E. D. The following is the formula representing the reaction:

$$6NH_4.\ P_2O_5.\ 24MoO_3 +$$
$$23Na_2CO_3 + H2O = (NH_4)_4.\ H_2P_2O_8 +$$
$$(NH_4)_2MoO_4 + 23Na_2MoO_4 + 23CO_2$$

It may be well to give a short *résumé* of this method. One gram of phosphate rock, or two or three grams of fertilizer are dissolved in nitric acid, and without evaporating to dryness diluted to 250 cubic centimetres. The solution need not be filtered. Twenty-five cubic centimetres of the solution are delivered into a four-ounce beaker and neutralized with ammonia—until a precipitate just begins to form—and then treated with five cubic centimetres of HNO_3 of 1·4 specific gravity. Ten cubic centimetres of a saturated solution of ammonium nitrate are added and the solution diluted to a volume of fifty to seventy-five cubic centimetres.

It is then brought to a full boil, removed from the lamp and five cubic centimetres of the *aqueous* solution of ammonium molybdate added. This is followed by a second and a third five cubic centimetres, if necessary, the precipitate allowed to settle, and filtered at once through a seven centimetre diameter filter. It is washed *thoroughly* with water by decantation and on the filter. The filter and precipitate are transferred bodily to the beaker. Standard alkali is then run in and at least 0·5 cubic centimetre of phenolphthalein (one per cent. solution) added, and then standard acid, until the color vanishes. Each cubic centimetre of alkali equals one milligram of phosphorus pentoxide.

THE METHODS OF TESTING FATS AND OILS.

By Dr. Ernest Mailliau.
Director of the Government Testing Laboratory at Marseilles, France.

[*Read at a special meeting, held June 8, 1893.*]

Dr. Wm. H. Greene, President, in the chair.

Dr. Mailliau spoke as follows:

Gentlemen:

The French Government and the Regency of Tunis have taken the opportunity of the great American World's Fair to bestow upon us the honor to communicate to you by conference and by practical experiments the analytical methods which we use in France to recognize the purity of the fatty bodies. I hope that you will give us your kind indulgence and facilitate our modest efforts with the good-will which you have already shown to all our fellow-countrymen who have come to you with the disinterested object of strengthening the scientific bonds which unite the two republics.

If the French and Tunisan Governments have chosen me for their representative, it is only because I direct the ministerial laboratory of technical tests founded for the purpose of studying all the products of the colonies and Mediterranean district, and especially oils and fatty matters as well

as the different products which are connected with them, and that I have acquired some knowledge of the subject by long practice and continual investigations.

This is the only laboratory of its kind, and has been placed at Marseilles, the great seaport of France and port of entry for colonial products.

The difficulties of chemical analyses of fatty matters are greatly increased, not only by the slight differences which characterize the various glycerides, but also by the numerous cases of isomerism, and the phenomena of oxidation and fermentation which modify their molecular structures, by the resins and the essential oils which they contain, and also by the foreign matters which injuriously affect them, and the composition of which varies infinitely according to the nature of the soil from which the plant draws nourishment, by the method of extraction, age, and a thousand other causes needless to mention.

Since the methods of communication have been facilitated, and exchanges have become more numerous, the different markets of the world have been flooded with fatty matters presenting different characters though of the same nature as those to which industry and commerce have been accustomed.

We have been led to seek methods of analysis for oils not by their impurities, which vary according to their origin, but by the examination of their principal constituents which remain practically the same for the same species.

For example, it is now well known, and we state with pleasure, since we have made the first of these observations, that the olive oil of Tunis, Morocco and other provinces often present the character of adulterated oils if analyzed without proper precautions, or by old processes.

Accordingly, the greater number of governments and large companies have been obliged to modify their specifications to control the purchases necessitated by their wants by methods better adapted to the needs of commerce and the progress of science. Accordingly, before trying the action of chemical reagents upon this product so extremely variable and alterable, it is indispensable for obtaining precise

results to submit the material to a purification preceded and followed by a number of filtrations. By thus removing the impurities which when present alter the results, we bring back the fatty bodies of the same species to a type which is always practically the same. To reach this end we work sometimes by washing with hot distilled water, sometimes with strong or dilute alcohol, sometimes we refine the fatty matter by the use of caustic soda lye (containing ten per cent. sodium hydrate), employed in the proportion of ten per cent. of the fat. The emulsion is poured upon a saturated solution of sodium chlorid and by the action of gentle heat, the different parts separate and the clear oil holding in suspension insoluble particles of soap rises quickly to the surface.

It is well to note that fatty matter, even when neutral, as has been demonstrated, dissolves notable quantities of alcohol, which must be eliminated, if this method of washing has been employed. The process of the operation cannot be fixed definitely; it varies according to the nature of the impurities and the object of the research.

It is certain, for example, in determining the amount of volatile acids we must be content with the simple filtration, and that when examining the oils of the cruciferæ we must not use caustic soda which changes organic sulphur to a soluble sodium sulfid. Having finished the preliminary operations, we may, according to circumstances, operate directly on the neutral fat or the fatty acids prepared from it.

The fatty acids collected in the nascent state (that is to say, when they rise to the surface in a pasty mass) have much stronger chemical affinities than when melted and de-hydrated. This difference is particularly remarkable in the examination of cotton-seed and sesame oils, the black and red colorations obtained very clearly with a mixture of five per cent. upon the nascent fatty acids are not visible with the same fatty acids when melted.

The purification skilfully made does not destroy the chemical characters of the oil, as is easy to verify, by treating comparatively the same oil containing five per cent. of

the fatty matter, the presence of which we wish to demonstrate. The reactions of the added material are in general intensified by these different treatments.

By working upon the fatty acids of the neutral oils, I have been able to demonstrate the purity of certain fatty matters which appeared adulterated and in which the presence of cotton-seed and sesame oils were indicated by the old methods which I have been able to revise.

(*Circulaire du Ministre de la Marine Française*, en date du 26 Juillet, 1892. *Rapport du Résident-général de Tunisie*, en date du 9 Mai, 1892. *Circulaires des Ministres du Commerce et de l'Agriculture*, etc.)

I well know that in practice these preliminary operations may appear very tedious, but I do not advise their use except in cases where adulterations have been indicated by the usual methods, and it is desired to make the proof positive.

Besides, I cannot understand why a chemist has always been expected in the analysis of such delicate materials as fats, to discover an infallible reagent, a single drop of which will immediately turn olive oil green, peanut black, sesame red, etc., so that any inexperienced person could discover adulteration and bring the perpetrator to justice. This requirement, of the most difficult part of verification, is absolutely incomprehensible and is only to be excused by the ignorance of those who ask it.

We will now proceed to the study of each oil in particular. We will pass rapidly over those which possess only a secondary interest, so as to lay greater stress upon those which are the object of a great number of sophistications, as for example, olive oil. But in the first place we will indicate rapidly the general processes, physical and chemical, which are used for the identification of the various fats.

GENERAL METHODS.

(1) *Specific Gravity.*—Specific gravity is taken with accuracy by the Mohr balance, which is too well known to need description. It must be borne in mind that the specific gravity of the same fat varies greatly with individual sam

ples, and this physical character is not sufficient to allow us to decide on purity or adulteration.

(2) *Action of Nitrous Fumes.*—We owe to a Marseilles gentleman, M. Poutet, the first serious proposition for recognizing certain adulterations of olive oil. It was designed especially to discover the presence of poppy-seed oil, with which at that time, olive oil was very frequently adulterated, and for which the process gave good results.

It is based upon the transformation of the olein to its isomeric modification elaidin, by the action of nitrous fumes. It has been modified by other chemists, Messrs. Boudet, Faure and Cailletet. The process of Mr. Cailletet was most sure and simple, and we use it in the following manner:

We take a tube 10 cubic centimeters long, $2\frac{5}{10}$ cubic centimetres wide, in which are twenty cubic centimeters of the fat to be analyzed. Six drops of pure sulfuric acid at 66° B. are added, the tube shaken one minute and then nine drops of nitric acid C. P. 40° B. are added, after which the tube is again shaken and then plunged in boiling water, where it is left exactly five minutes, after which it is cooled in a water-bath at 8° to 10° C., whence it is taken at the end of two hours, and the condition of the mass observed. It is well to note the different colorations obtained. First, after the addition of the sulfuric acid; second, after the addition of nitric acid; third, after the removal from the water-bath, and fourth after chilling.

(3) *Sulfuric Saponification.*—M. Maumené proposed to observe the rise of temperature produced by rapidly mixing sulfuric acid with oil. The manner of applying the process in our laboratory is as follows: fifty grams of the fat for analysis are weighed into a conical glass of 100 cubic centimeters capacity. The temperature is noted and ten cubic centimeters sulfuric acid, 66° B. at the same temperature as the oil, is added. The two liquids are stirred together for one minute. An accurate thermometer is then immersed in the upper portion of the mass, stirred slowly, and the maximum temperature noted. The initial temperature must be at least 20° C. In order to obtain exact results

it is well to make several determintions and take their mean, when the variation does not exceed 2° C.

To obtain the relative sulfuric saponification, we note the rise of temperature obtained with fifty grams of distilled water at the same temperature as the oil and ten cubic centimetres of the same sulfuric acid. The number of degrees obtained by the oil is multiplied by 100 and the product divided by the number of degrees obtained with water. This process has the advantage of giving results nearly constant with acids of somewhat different strength. I have tried the application of the sulfuric saponification with semi-solid vegetable oils, by working at 2° or 3° above their melting points, and the results have been very satisfactory, especially for palm-nut oil and cocoanut oil, because the differences between them and the fluid oils often amount to 45° or more, as, for example, between palm-nut oil and sesame oil.

(4) *Iodin Number.*—In the fatty bodies there are members of unsaturated series, as, for example, oleic acid, which can absorb into its molecule as many atoms of the halogens as there are lacking atoms of hydrogen for complete saturation. The iodin number of olive oil varies between 80 and 84, that of peanut oil is 97, while that of cotton-seed oil is 108. These differences then allow, within certain limits, the determination of the purity of the various fats. We apply the Hübl method as follows:

Solutions required:

Alcoholic solution of iodin,	50	grams.
Solution of hyposulfite of sodium,	24·8	grams per litre.
Solution of mercuric chlorid,	60	grams per litre.
Solution of potassium iodid,	100	grams per litre.

Five grams of fatty acid are weighed out, diluted to 100 cubic centimeters with alcohol ninety-two per cent.; ten cubic centimeters of the solution are taken and to it added twenty centimeters of the iodin solution and fifteen to twenty cubic centimeters of the solution of mercuric chlorid. The flask is closed and allowed to stand three hours. Twenty cubic centimeters of the potassium iodid solution

are added and the excess of iodin titrated. When the brown coloration begins to disappear a few drops of starch solution are added and then hyposulfite until color disappears.

We will pass in silence the other indices, such as that of acetyl, which is of use only to discover castor oil.

(5) *Freezing Point.*—The freezing point is easy to determine by means of a thermometer and a freezing mixture.

(6) *Melting Points of Fatty Acids.*—The dry and melted fatty acids are sucked into a capillary tube. After solidification the tube is placed beside the bulb of a sensitive thermometer and immersed in a beaker of water, the temperature of which is raised very slowly.

The reading of the thermometer is taken the instant the body passes from the solid to the liquid state.

(7) *Solidification Point of Fatty Acids* (*Titer.*)—The dried and melted fatty acids are placed in a tube 15 centimeters long and 2 centimeters in diameter, which is suspended in a wide-mouthed bottle with a perforated stopper. A thermometer graduated to tenths is inserted so that the bulb reaches the centre of the material. At the moment solidification commences a circular movement is given to the thermometer, stirring the whole mass; the thermometer is then left at rest and carefully watched till the mercury ceases to rise, the reading then taken gives the point of solidification, or titer, conventionally adopted.

(8) *Saturation.*—We operate on five grams of the melted and dried fatty acid with a solution of normal caustic soda. The number of cubic centimeters absorbed give the saturation number.

(9) *Solubility in Absolute Alcohol.*—We determine this in the following manner: the fat is neutralized by agitating in a closed separating funnel for thirty minutes with twice its weight ninety-five per cent. alcohol. After settling it is drawn off and the alcohol held in solution driven off at low temperature, after which it is agitated at 15° C., or at a few degrees above the melting point; or if solid at 15°, with twice its weight of absolute alcohol. A known quantity of this alcohol is evaporated, the residue weighed, and the quantity of oil dissolved by 1,000 grams of alcohol is calculated.

FLUID VEGETABLE OILS.

Olive Oil.—Olive oil, like other vegetable oils, is a mixture of neutral glycerids, olein, stearin, palmitin, etc., and a variable quantity of free fatty acids. It is the edible oil *par excellence*, and the south of France owes a portion of its prosperity to the cultivation of the olive tree. This culture is to-day almost precarious in certain countries, though the consumption continually increases and olive oil always enjoys the just title of uncontested superiority. We can only attribute these remarkable results to the adulterations made for the purpose of selling under the name of olive oil, seed oils, or adulterated olive oils. We would be easily freed from these adulterations if chemists had at their disposition absolutely sure means to recognize them. Unfortunately the similarity of composition and reaction of the various vegetable oils render the demonstration of their presence extremely difficult. In face of the prejudice caused by adulteration, the greatest efforts have been made to solve the problem, and although the results have not been sterile they have not yet reached a satisfactory solution. It is necessary to say that if certain adulterators succeed in selling seed oils disguised as olive, they reverse the problem for the chemist by making him seek olive oil in seed oil. I may remark that the fraud is not always so great, very often the proportion of seed oil is not higher than ten per cent. Consequently, for our methods of analysis to be considered absolutely good, they must give results without recourse to comparisons which are satisfactory to show five per cent. in a mixture. Under these conditions we will be certain to discover adulteration when made in the proportion of ten per cent.

Let us rapidly review the general processes for the recognition of arachide, sesame, cotton-seed and poppy oils in olive oil; and we must acknowledge that none of them demonstrate less than ten per cent.

Specific Gravity.—The specific gravity of olive oil varies from ·915 to ·918; we have ·917 to ·918 for undecorticated peanut; ·921 for decorticated peanut; ·923 for sesame; ·921 to ·924 for cotton-seed oil; ·924 for poppy oil. These

variations of density in the olive oil do not allow us to recognize a mixture with any degree of certainty.

Action of Nitrous Fumes.—When taken from the water-bath, if the oil contains a fairly large proportion of peanut oil, it will appear wine-red. Pure olive oil is, on the contrary, lemon-yellow. When taken from the cold bath a complete solidification is observed with pure olive oil, which has the appearance of very light fresh butter; with a mixture of fifteen per cent. of all other oils there is no solidification. This method gives good means of detecting peanut and poppy oils in edible oils, but is of less use when applied to oils used for industrial purposes, which may not solidify, though pure.

Sulfuric Saponification.—The rise of temperature of olive oil is 35°; the relative, 94°. A rise of temperature above 35° usually indicates adulteration, equal or lower results do not absolutely indicate purity, because certain pure olive oils give only 31°, 32° and 33°, and, in consequence, after the addition of seed oil, show only 34° to 35°.

Indices.—The iodin number varies from 80 to 85, and in a certain measure helps us to discover seed oils. It likewise offers us a quantitative method with a mixture of known oils. The variations in composition of the same oil vitiate its sensitiveness for determining mixtures from five to ten per cent.

We will not mention the other general processes, but will dwell particularly on the special reactions which characterize the presence of three oils most frequently used to adulterate olive oil, to-wit: peanut, sesame and cotton-seed.

These processes have a much greater analytical value than the general ones, for if in the course of analysis we find unsatisfactory results with the latter, we can detect adulterations with certainty by the former.

Examination for Peanut Oil.—The density is almost the same. The sulfuric saponification, and above all, the Cailletet process gives us good results, but only the presence of arachidic acid $C_{22}H_{44}O_2$ (melting point, 75°) allows the sure recognition of the presence of peanut oil.

We have adopted, with slight modifications, the method of Renard. Twenty grams of the oil are saponified by twenty cubic centimeters of a caustic soda solution of 36° B., diluted in 100 cubic centimeters, alcohol ninety per cent. The soap formed is precipitated by a fifty per cent. solution, in alcohol, of lead acetate which must be neutral. After complete precipitation, decant while warm, and wash the residue with alcohol, which after being ground in a mortar is agitated with 200 cubic centimeters of ether. This operation is repeated three times to remove the last traces of lead oleate soluble in ether. The residue is then put in a porcelain dish containing two or three liters of distilled water and fifty cubic centimeters hydrochloric acid. When decomposition is complete the solution is decanted and the fatty acids washed with distilled water, after which they are dried in an oven to remove the last traces of water, when they are dissolved in forty cubic centimeters of ninety per cent. alcohol. A drop of hydrochloric acid is added and the mixture chilled to 15°. Peanut oil gives a generous deposition of arachidic acid crystals. These are washed twice, using twenty cubic centimeters each time, of ninety per cent. alcohol, then three times with twenty cubic centimeters each time of seventy per cent. alcohol, in which arachidic acid is completely insoluble. The washing is complete when a few drops gives no residue on evaporation. The acids are warmed slightly and treated with boiling absolute alcohol. After filtration the alcohol is evaporated in the oven at 100°, till the weight of the residue remains constant. If the melting point of the residue is between 73° and 75° we can affirm the presence of peanut oil. We must be sure of the freedom of the fatty acids from all traces of oleic acid, which prevents their crystallization. This elaborate but truly scientific process must be carried out only by skilled hands.

Examination for Sesame Oil.—To recognize sesame oil in olive oil we can use the specific gravity, the sulfuric saponification and Cailletet process, but especially the method which we use in our laboratory, and which consists of the reaction of hydrochloric acid and sugar upon the fat.

We do not operate on the glycerid, but on the derived fatty acids. If the oil is operated on directly, we can obtain a red or pink coloration with a perfectly pure olive oil. I have frequently observed this coloration in my laboratory with olive oils from Tunis, Algiers, Molfetta, Bitonto (Italy), and more rarely with those from Provence. This coloration comes from the coloring matter dissolved in the juice which flows out along with the oil from the presses. This can be shown by treating the separated juice with hydrochloric acid and sugar, with which it gives a coloration exactly resembling that given by sesame oil. It is therefore of the highest importance to work with pure fatty acids, according to the process I am about to describe, and which has been called the Milliau process.

Method of Operating.—We saponify fifteen cubic centimeters of the fat under examination with ten cubic centimeters of the solution of caustic soda, 36° B., with the addition of ten cubic centimeters ninety-two per cent. alcohol. When the boiling mixture becomes clear we add 200 cubic centimeters hot distilled water and boil to expel the alcohol; then decompose with ten per cent. sulfuric acid. The fatty acids are removed from the surface in the pasty state and washed by shaking in a test tube with cold distilled water, after which they are heated in an oven to 105°. When the greater part of the water is eliminated and they commence to melt, we pour them on half their volume of pure hydrochloric acid, which has been saturated in the cold with finely pulverized sugar. The mixture is shaken violently in the test tube. The presence of sesame is always distinctly indicated by the rose or red coloration of the acid solution; other oils leave the acid colorless or communicate to it a slightly yellowish tinge.

This reaction is extremely delicate and permits the sure recognition of the presence of one per cent. of sesame oil not only in olive oil but in all fatty mixtures as well as in soap.

This process was presented before the Academy of Sciences by M. Debray, February 20, 1888, and was awarded the gold medal of the Société d'Encouragement. (Report

of M. Muntz, in the name of the Agricultural Committee, February 20, 1889.)

Examination for Cotton-seed Oil.—Until recently, the detection of cotton-seed in olive oil was considered impossible, and accordingly, the different scientific societies and several chambers of commerce promised great prizes to the inventor of a process which would detect this adulterant.

Two methods were proposed simultaneously—one by M. Bechi, the other by myself. These two proccesses, which at first sight appear quite analogous and based upon the same reaction, differ completely from the scientific standpoint as well as in the exactness of the results obtained. M. Bechi has based his process upon the direct action of silver nitrate upon the oils. As long ago as 1878, we made some experiments with M. Puget of a similar nature, and the uncertainty of the reactions led us to abandon them entirely.

M. Bechi's process possesses the serious inconvenience of causing us at times to reject as adulterated, oils which are absolutely pure, and thus work injustice and create a considerable prejudice against the firms which have sold them. From results obtained at the Institut National Agronomique of Paris, as well as in other laborotaries, a deep coloration has been found with oils absolutely pure. Outside of these inconveniences, which are sufficient to cause us to throw it aside, it has a defect of being based upon a coloration having no well-defined chemical character, and it produces effects with different substances, the action of which it is impossible to explain. The use of colza oil has the serious fault of bringing into the reaction a second oil which may be impure and completely vitiate the results. Finally, the conclusions reached by the Italian scientific commission, instituted at Rome by act of the ministry to study the Bechi process, show that it is not certain on quantities of less than fifteen per cent. It solves the problem of finding less than ten per cent. no better than the Cailletet process, which shows the presence of fifteen per cent. The same commission declared also that olive oil containing glycerin, free fatty acid, formic acid, acetic acids, does not give a sure

reaction with the Bechi reagent. Now, since all olive oils contain free fatty acid from several tenths of one per cent. for virgin oil to 100 per cent. in some industrial oils, what conclusions can we reach?

The Bechi process will give, from fifteen per cent. up, a brown coloration of variable intensity, but in oil containing cotton-seed oil, which is fresh and well refined, the only sort used for edible purposes, we have a very weak reaction; while with an olive oil perfectly pure, but containing organic or mineral matters in suspension or solution, which have an action upon the reagents, we should have a pronounced coloration.

That is why I gave up these uncertain and variable results obtained in 1878 and studied the action of the nitrate of silver not upon the oil itself but upon the products of saponification derived from it. The results obtained exceeded my expectations, and have been published by the press as the Milliau process.

[*To be concluded*]

THE ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting held Wednesday, September 27, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 27, 1893

The stated meeting of the Electrical Section was called to order at 8.10 P.M. by President Willyoung, with twenty-one members and visitors present.

The minutes of the meeting of June 27th were read and approved.

The Treasurer reported a balance of $35.89 on hand, and presented bills for printing $3, and postage and mailing of notices $8.75, which were ordered paid.

A paper on "The Chloride Electrical Storage Battery," by Mr. Herbert Lloyd, was read by the author and discussed by Messrs. Hering, Spencer and Willyoung.

The meeting then adjourned.

R. H. LAIRD, *Secretary.*

SOME INTERESTING PECULIARITIES OF THE ALTERNATING ARC LAMP.

BY THOMAS SPENCER.

[*Read at the meeting of the Electrical Section, held June 27, 1893.*]

Although arc lighting by means of direct currents has been practised in this country for nearly fifteen years, it is only quite recently that an attempt has been made here to utilize the alternating current for that purpose, although it is a historical fact that the very first attempts made to introduce arc lighting for street illumination was by means of such a current. I refer to the Joblochkoff candle. Joblochkoff found that he had to use an alternating current to make his two carbon pencils, which composed his candle, burn away equally. Since Joblochkoff's time there has been a great deal of work done in Europe, and especially in Germany, where greater progress has been made in the electrical sciences than any other part of the eastern continent, towards utilizing the alternating current for arc lighting, and I have the pleasure of showing you one of the latest productions of that country (both as to lamp and carbon to be used with it) this evening. The lamp itself, though, being an American production, it being manufactured by the Helios Electrical Company, of Philadelphia, under patents of the German company of the same name. This lamp I will speak of later.

As I said before, it is only quite recently that alternating currents have been utilized for arc lighting. The first systematical attempt of the sort was, no doubt, that of the pioneers of alternating currents in this country, the Westinghouse Electrical Company, of Pittsburgh, Pa., when they put upon the market their well-known alternating series system. This was, no doubt, brought about by a circumstance, and that circumstance was the invention by Mr. William Stanley, who was then consulting electrician for

that company, of a wonderful constant current alternating current dynamo. This machine I look upon as one of the most beautiful in its performance of anything in the whole range of electro-dynamic machinery. It was my pleasure to be so situated as to have the handling of two of the first machines of this kind sent out by the company, the performance of these machines were simply wonderful. I have time and time again switched one of these machines from full load; that is, sixty arc lamps, each taking forty-five volts, to a dead short circuit, with only a variation of a half ampère in the current, and this without any mechanical regulation. I would say, in passing, that with this machine the only thing to be feared was an open circuit, and that the safe way to run the machine was dead short circuited.

The principle on which this machine worked was very vaguely understood for some time, the inventor himself having a very complicated explanation, based on armature reaction, but no doubt the correct explanation is this: The machine has an armature of the tooth form, on which there is wound quite a large amount of wire, and as a result the electro-motive force generated by the machine is quite large, but on account of the way the armature is constructed there is a large self-induction. These two factors being so great the actual resistance in the current becomes insensible in comparison with them, so the current is practically independent of the resistance in circuit; or, in other words, constant.

This can more clearly be seen from the following equation:

Where

c, is the current.
E, the electro-motive force.
R, the total resistance in the circuit, including the resistance of the arcs of the arc lamps.
L, the coëfficient of self-induction.
$p = 2\pi n$, where n is the frequency.

$$c = \frac{E}{\sqrt{R^2 + L^2 p^2}}$$

Now, if E and L are very large in comparison to $L\,R$, we have

$$c = \frac{E}{L\,p}$$

or the current is constant, no matter what the external resistance may be, providing it is not too large.

With such a machine the Westinghouse Company thought they had solved the problem of arc lighting by means of alternating currents, but in this they were mistaken; in fact, this was really the easiest end of the problem, and although this machine has now been known for over three years, this system has made little progress, due to

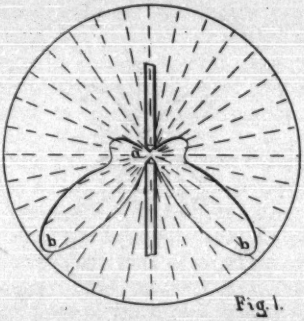


Fig. 1.

the fact that these lamps did not come up to the standard set by the direct system in common use.

The fact is, that here in this country an alternating current arc lamp has been studied entirely in those lines on which a direct current lamp was found to give the best results, while European practice shows plainly that a treatment entirely different should be followed.

Let us study the arcs formed by the two kinds of currents; first, as regards the distribution of their illuminating power.

Let *Fig. 1* represent the two carbon pencils in a direct arc lamp, where the upper pencil is supposed to be positive. Suppose we take *a*, the arc, as a centre of a circle,

and suppose we plot off on each radii the candle-power in the direction represented by it. Now, if we trace a curve through all the points thus found, we have a curve, as shown in *Fig. 1*, from which we see that nearly all the light is thrown down in the direction *a b*. This is due to the fact that nearly all the light from an arc lamp comes from the crater on the positive carbon.

Fig. 2 shows the curve for an alternating arc, which you see is altogether different from the first curve, there being four wings instead of two, as in the first curve, and these wings are shorter.

This distribution of light, of the alternating arc, has

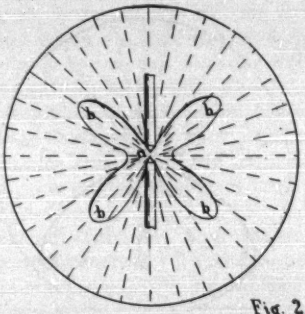


Fig. 2.

always been looked upon as a failing, for the light represented by the two upper wings is usually thrown up and wasted, especially if the lamp is out of doors. This defect has been in a great measure remedied in the lamp before you, by making the lamp focusing; that is, making the arc remain always in the same place, and using a white reflecting plate close above the arc. This plate will reflect something like eighty per cent. of the light incidenced upon it. There is another point in which there is a great difference in the two currents, it is this: One of the first things noticed about the alternating current, was that there was very little arcing at switches where currents of large ampèrage were broken. This pecu-

liarity was looked upon as a particularly valuable feature for, in the construction switches, the arcing was the principal thing to be guarded against, especially where high voltages were to be broken. I think, with the general introduction of alternating current plants, this property is not appreciated. One has only to stand and watch the arc that follows a plug switch in a direct arc switch-board, where the voltage is not over 2,500 volts and ten ampères, and to imagine what the result would be if the alternating current should suddenly acquire the same property, on some of the beautiful switch-boards for incandescent lighting of about the same voltage and much larger ampèrage, when the switches began to be thrown. There has been a great many theories about this property of the alternating current, but it is about settled that it is due to the fact that at a certain instant there is no current flowing to keep up the temperature of the vapor through which the current is flowing, sufficient to maintain a strong, hardy arc, and as a result it is easily broken. Now, this property, although it is just the thing we want, as far as switches are concerned, is far from desirable when we come to use the alternating current for arc lighting. It is evident from what has been said that an alternating arc is much less hardy than that of a direct current, of the same current density. We see, therefore, that it is a mistake to follow the lines of the direct system in devising an alternating system. What is desired is to get as much heat generated as possible in the flame, so as to keep up the temperature of the vapor through the time when the generation of heat practically stops for the instant. This is best illustrated by *Fig. 3*, where *a a a* is the current curve and *f f f* the temperature curve of the flame for the same instants, and *c c c* the minimum temperatures, which the flame reaches. Now *c c c* will be larger the larger the current, and the arc will be more hardy.

So it would seem that the only way to produce a good alternating arc lamp, is to use a large current, but a large current means a large candle-power, unless we lower what is called the counter electro-motive force of the arc, or the

drop in electro-motive force which occurs at the crater itself. If we refer to *Fig. 4*, where *A* and *B* are the carbon points, the distance between them being exaggerated for convenience, and suppose the drop in potential plotted from one point to the other, assuming *A* the positive carbon, we find for the direct system, at the point *a;* that is, at the crater, that there is a sudden drop of the potential to a point marked *b*. This drop is what is known as the counter electro-motive force of the arc. For the remaining part of the distance the drop is more gradual, and varies as the current. This is the part due to the drop in the flame itself. So it is apparent that if we could reduce the counter electro-motive force, leaving as large a loss of energy in the flame as possible, we would get an arc which would be much less affected

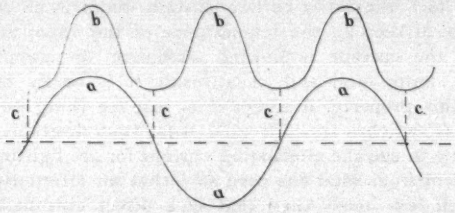


Fig. 3.

than with a smaller current, at the same time without any larger output in watts for the lamp. This has been done in the lamp before you by the use of a special low voltage carbon, which allows this lamp to give an illuminating effect with twenty-eight volts and ten ampères, equal about that given by a forty-five volt seven ampère direct-current lamp. Referring again to the counter electro-motive force, I would say that there has been a great deal of controversy over whether such a thing really existed. I myself am one of the party who believe in its existence. In fact, there is a strong current setting in the direction of that belief. I myself have been convinced that there was a real electro-motive force in the arc by studying the alternating arc itself; in fact, there are reactions in the arc which could only be

explained by the existence of a counter electro-motive force. A gentleman in England, whose name I have forgotten, has recently tried an experiment of heating a carbon juncture in a hydroxygen flame, and was able by this carbon thermo-pile to get quite a difference of potential between the two carbons. He claims that his results were such as to account for the counter electro-motive force of the carbons had been raised to the temperature of the arc. Also quite recently Sylvanus Thompson has tried quite a number of experiments bearing on this subject, and has come to the conclusion that the electro-motive force is the result of the energy which disappears as latent heat in the volatilization of the carbon in the crater.

There is another peculiarity of the alternating arc which is the most serious objection to it, from a commercial stand-

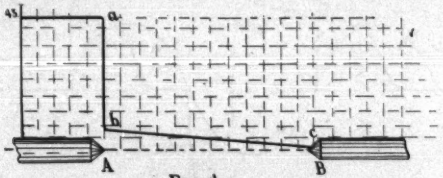


Fig. 4.

point, and that is the noise made by the arc. Even this has been attacked, and so overcome that it is no longer the objection it was in the early forms of lamps using alternating currents. The cause of this noise is due to the constant variation of temperature of the flame, as I have described already, which produces an expansion and contraction in the surrounding air. The result is a musical note depending on the frequency of the current. That there is a real rise and fall, even in the light given out by the arc, can be shown by moving a white stick, or better a short piece of white wire moved back and forth rapidly near the lamp, when the white band, caused by the persistence of impression in the eye, will be observed to be broken up into bands, showing that the light is varying with the alternations.

The noise is, I find, a function of the form of the current curve. This came under my notice in trying to substitute a choking coil in place of a resistance to absorb the excess electro-motive force above what was wanted at the arc. I noticed that the noise was considerably increased by the coil over the resistance. You can see that this is the case by the experiment I have arranged before you, which is so wired that either the resistance or coil can be used. You will observe that when the lamp is burning on the coil, there is considerable more noise than when the resistance is in circuit. The reason why this is the case will be explained by referring to *Fig. 5*, where let *a a a* be a simple curve of sines, which is very near the case, with a well-designed alternating dynamo. Let this curve be deformed

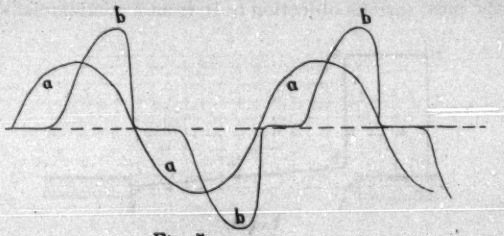


Fig. 5.

by the current represented by it, passing through a choking coil with iron. The deformed curve will be something like the curve *b b b*, due to the lack of constancy of the permeability, and to hysteresis in the iron. If we look at this curve we will notice an abrupt rise in it, which means a sudden rise of temperature in the flame; or, in other words, we would have a sort of explosion, and as a result this form of current curve would be more noisy. There is no doubt but the form of the current curve, which would be the best as far as sound is concerned, is that of the simple sine curve, for in this curve the current rises gradually, and sinks away gradually.

One thing which puzzled me for some time was that I found that a choking coil, which contained no iron, even

made more noise than when a resistance was used. As there was no changing permeability or hysteresis, in the arc, the cause for this increased noise was not quite so apparent. The explanation, no doubt, lies in the fact that no machine gives a true sine curve, but in most cases the curve is symmetrical as regards the rise, and fall, as will be seen by the curve *a a a*, *Fig. 6*, which is supposed to be the form of curve given by the dynamo. Now, a choking coil without iron would deform this curve to the form shown in the curve *b b b*, on account of the change of phases which it would bring about in the different harmonies which make up the compound wave coming from the dynamo.

It is found that when the frequency is reduced the noise is greatly decreased; for instance, lamps burned by means

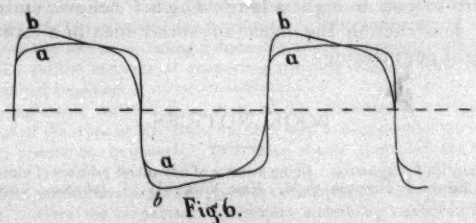


Fig. 6.

of the current supplied by some dynamos recently turned out by the Westinghouse Electric Company, which have a frequency of 7,200, practically made no noise. On the other hand, Mr. Tesla, by going the other way; that is, by raising the frequency above the audible point, made a perfectly quiet arc, but as high frequency introduced so many other objectionable features, I hardly expect to see this method very extensively introduced.

There is what you might call, still, a mechanical way by means of which the noise can, in a measure, be reduced, and that is by running with a short arc. The reason for this is self-evident, for by so doing you keep the flame well inside the hot walls of the carbon, which do not fluctuate as much in temperature as does the flame; as a consequence

the surrounding air is not so much affected, and the result less noise.

I will say in closing that an alternating arc lamp is something very much to be desired, as it forms one of the links in a chain towards which all electrical engineering is now drifting. I refer to the designing of a central station so that all kinds of electrical work can be done by one kind of current, which can be supplied by one kind of machinery at the central station. Not as now by several different kinds, as I saw to-day, a station using at least five different kinds of dynamos. That the alternating current is to be the current settled upon no one will deny, on account of its great flexibility. Therefore, I believe the alternating arc lamp has a great future before it, even greater than the series arc has had in the past. It, therefore, gives me pleasure to exhibit to you to-night a lamp, which I believe, embodies in its construction the most advanced idea in alternating arc light engineering.

BOOK NOTICES.

Electricity and Magnetism. Being a series of advanced primers of electricity. By Edwin J. Houston, A.M. New York: W. J. Johnston Company, 1893. 12°.

Electrical Measurements, and other advanced primers of electricity. By Edwin J. Houston, A.M. New York: W. J. Johnston Company. 1893. 12°.

The name of Professor Houston, recently elected President of the American Institute of Electrical Engineers, the highest honor within the gift of American electricians, is so widely known, not only as an eminent authority on electrical subjects but also as a scholar and author, that the intrinsic goodness of the above recently-published works might almost be assumed without investigation.

The two works noted above form part of a series of text-books which Professor Houston has in hand, and which are designed to simply and clearly elucidate the fundamental laws of electricity and the principal facts connected with its distribution and measurement. The first-named work is intended to bring out *principles* and *fundamental* facts rather than to have to do with *applications* of principles. Beginning with a brief historical retrospect the main phenomena of static electricity, the nature of insulators and conductors, the phenomena of electric discharges, the various dynamic, thermal and voltaic sources of electricity, are entertainingly and instructively dealt with; following these chapters are others devoted briefly to electro-

receptive devices, *i. e.*, the motor, the arc and incandescent lamp, the storage battery, telephone, etc.; to a discussion of the *nature* of the electric current; to the system of units by which electricity is measured, etc. The various *kinds* of circuits, magnetism and the electro-magnet also receive full treatment.

The second work deals with applications rather than with laws; though entitled *Electrical Measurements* the larger portion of the work is devoted to a detailed consideration of the practical side of electricity with which the engineer and commercial electrician has principally to deal. The different kinds of voltaic cells are described and their advantages and disadvantages, with reference to different kinds of work mentioned; a brief mention is also made of the selenium and other better-known thermal cells. Following is an outline of the various systems of heavy electrical distribution, such as the Brush, Edison and Thomson-Houston systems; the series, multiple series, and other methods of coupling up receptive devices. Arc lighting is given a chapter by itself, as is also incandescent lighting. Alternating currents, as is right by virtue of their rapidly growing importance, receive an especially exhaustive treatment; the nature of the current; the construction of the alternating machine, etc., being clearly brought out; a separate chapter is devoted to the induction coil and transformer. This construction of dynamo machines and motors, including a discussion of the commutator and its function, the various methods of connecting armature sections, fields, etc., also receives full treatment.

An agreeable surprise in a work of this character is an interesting account of the work of Mr. Tesla, together with a discussion of the high-frequency phenomena in general. This alone should commend the book to students.

About seventy-five pages are given to the subject of "Electrical Measurements." Here the fundamental principles underlying measurements are explained. Measurements by means of the calorimeter and voltameter are discussed and a number of the necessary constants given. The sine, tangent and differential galvanometer are well explained, as also the electro-dynamometer, the construction of resistance boxes and the construction and method of use of the Wheatstone's bridge.

An admirable feature of both these books is the selection of pertinent quotations from standard works at the end of each chapter; these quotations are designed to interest the student in these more elaborate and exhaustive works. Another feature, which will be appreciated, is the summary of the entire work which is made in the last chapter; this is of great assistance in refreshing the memory.

These works are well bound and printed on good paper, in clear type. The illustrations are numerous and clear, though somewhat lacking from an artistic standpoint. The books are heartily commended to beginners as well as to electrical workers, who have had but small educational facilities, and desiring further knowledge; in them they will find much which will assist them in their daily work as well as a stimulus to further study.

E. G. W.

Practical Astronomy. By P. S. Michie and F. S. Harlow. Second Edition. New York: John Wiley & Sons. 1893.

Lord Bacon stated that mathematical science is the handmaid of natural philosophy. It is still more the handmaid of astronomy. And in this treatise on practical astronomy the authors have presented a book that describes the actual methods in use in an observatory, in field work, in explorations and in surveys. There has, of late years, been a superabundance of treatises on observational astronomy; treatises that, while valuable in their descriptive parts, make no pretension to being of service to the scientific working out of the various problems of astronomy. They are, in fact, intended for the star gazer, the *dilettante* and the general reader. The work before us, as stated in the preface, is designed especially for the use of cadets of the United States Military Academy. The usual methods of determining time, latitude and longitude, together with the requisite formulæ, are given. The construction of the ephemerides of the sun, moon and of a planet is explained, as are also the determination of azimuths and the projection of solar eclipses. The principal instruments in use are illustrated and their adjustments and uses described. P.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, October 18, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 18, 1893

JOSEPH M. WILSON, President, in the chair.

Present, eighty-four members and thirty-two visitors.

Additions to membership since last report, four.

Mr. Hexamer continued his remarks descriptive of the World's Columbian Exposition, illustrating the subject with a series of lantern views of buildings, grounds and interiors.

The Secretary's monthly report contained references to the present difficulties of the Nicaragua Canal Construction Company, the rapid growth of the electric railways in American cities, the extension of the applications of special steels for various constructive uses, etc, The Secretary also gave a further description of the process and machinery of the American Wire Glass Manufacturing Company, which had just started in operation an extensive plant at Tacony, Philadelphia. He also invited attention to a graphical chart prepared by the Geo. F. Blake Manufacturing Company, to illustrate the low efficiency of the present pumping engines supplying the city with water.

Adjourned. WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR SEPTEMBER, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 30, 1893.

GENERAL REVIEW.

September's normal temperature is about 63°.1, and its normal rainfall 3.53 inches. The present month opened decidedly cool, light frosts occurring in elevated regions on the 2d and 3d. From this time until the 25th, the temperature ranged not far from the normal, excepting a few days of warm weather about the 20th. A decidedly cool wave overspread the State on the 25th, after which cool weather continued till the close of the month.

Throughout the Delaware and Susquehanna basins, excepting the mountain and valley districts along the lower Susquehanna, the rainfall was evenly distributed, though slightly below the normal. A marked deficiency of precipitation occurred in the Ohio, Lake and Potomac basins, the deficiency amounting at most stations to one and a half or two inches. Severe local storms occurred on the 7th and 15th, the latter accompanied by general rains throughout the State. That of the 7th was particularly severe in the northern counties, and especially so in Tioga, where great damage was done to property and not a few lives lost. Observers' reports show that the storm had the appearance of a tornado. The barograph at Emporium recorded a marked though not very great fluctuation. The storm of the 15th was more general and not so destructive, but was violent in some sections.

At Philadelphia the total excess in rainfall for the month was 0.33; at York a deficiency of 2.41; Harrisburg, deficiency, 2.77; Pittsburgh, deficiency, 0.77, and Erie, deficiency, 3.01 inches.

Monthly Summary of Reports by Voluntary Observers of T

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level.			Temperature.								
							Maximum.		Minimum.					
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.
Allegheny,	Pittsburgh, A,	820	30·04	30·33	29·80	65·0	88	19	35	29	74·8	55·8	19·0	33
Berks,	Hamburg,	380	. . .	. . .	. . .	62·4	86	5	37	28	73·0	51·9	21·1	36
Berks,	Reading, A,	280	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Blair,	Altoona, B, (28 days),	1,181	. . .	. . .	. . .	63·9	85	6, 8	33	27	74·4	53·4	21·0	39
Blair,	Blue Knob, A,	2,500	. . .	. . .	. . .	58·8	80	5	34	26, 29	65·5	52·2	13·3	24
Blair,	Hollidaysburg,[1]	947	. . .	. . .	. . .	61·5	89	5	26	30	73·4	46·7	26·7	40
Bradford,	Wysox[1],	718	30·06	30·35	29·61	58·6	83	5	32	30	68·9	46·5	22·4	37
Bradford,	Le Roy,	1,400	. . .	. . .	. . .	58·5	78	5	36	27	67·4	49·7	17·7	32
Bucks,	Forks of Neshaminy[1] (29 days),	304	. . .	. . .	. . .	62·6	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Bucks,	Quakertown,[1]	536	30·03	30·33	29·69	60·1	86	19	35	28	72·2	50·1	22·1	34
Cambria,	Johnstown, A,	1,184	30·08	30·36	29·83	65·9	89	7	32	30	74·7	57·1	17·6	40
Cameron,	Emporium, A (26 days),	1,050	30·06	30·41	29·74	59·6	84	7	34	29, 30	69·6	49·6	20·0	36
Carbon,	E. Mauch Chunk,	550	. . .	. . .	. . .	59·7	83	5, 19	35	28	70·8	48·6	22·2	39
Centre,	State College[1]— Agricultural Experiment Station,	1,191	30·01	30·30	29·72	60·0	87	5	30	27	69·0	47·7	21·3	43
Chester,	West Chester,[1]	455	30·05	30·30	29·70	62·9	86	19	41	30	72·5	54·7	17·8	27
Chester,	Coatesville,[1]	380	. . .	. . .	. . .	59·1	89	19	36	29	73·3	50·4	24·9	40
Chester	Kennett Square, A,[2]	375	30·08	30·36	29·83	64·3	88	19	39	28	75·4	53·3	22·1	34
Chester,	Phœnixville, A,	190	30·07	30·34	29·66	64·2	87	19	39	28	74·4	54·0	20·4	33
Chester,	Westtown (30 days),	350	. . .	. . .	. . .	60·8	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Clearfield,	Grampian (26 days),	1,450	. . .	. . .	. . .	59·2	82	5, 19	32	27	68·7	51·6	17·1	34
Clinton,	Lock Haven,[1]	560	. . .	. . .	. . .	60·3	89	5	33	30	73·2	48·7	24·4	41
Columbia,	Bloomsburg, A— State Normal School,	500	. . .	. . .	. . .	60·3	84	5	37	30	70·2	50·5	19·7	34
Crawford,	Meadville (27 days)— Divinity Hall,[1]	1,200	. . .	. . .	. . .	60·6	84	7, 15	31	29	72·2	49·0	23·2	36
Crawford,	Saegertown, A,	1,200	. . .	. . .	. . .	59·7	86	5, 15	28	28	71·7	47·7	24·0	33
Cumberland,	Carlisle,[1]	480	. . .	. . .	. . .	62·0	90	19	34	30	75·2	51·8	23·4	30
Dauphin,	Harrisburg, A,	361	30·06	30·38	29·72	63·0	86	19	41	27	71·3	55·4	15·9	32
Delaware,	Swarthmore, A— Swarthmore College,	190	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Erie,	Edinboro,[2]	1,400	. . .	. . .	. . .	58·9	80	7, 15	35	28	. . .	. . .	. . .	. . .
Erie,	Erie, A,	681	30·02	30·29	29·78	62·0	86	7	42	30	68·0	55·0	13·0	29
Fayette,	Uniontown,[1]	1,000	. . .	. . .	. . .	64·4	87	7	32	29	74·5	54·4	20·1	31
Franklin,	Chambersburg,[2]	618	. . .	. . .	. . .	65·0	87	20	37	30	74·9	55·2	19·7	37
Fulton,	McConnellsburg,[1]	875	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Huntingdon,	Huntingdon, A— The Normal College,	650	. . .	. . .	. . .	61·0	90	5	32	30	73·3	48·7	24·6	43
Indiana,	Indiana— State Normal School,	1,350	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Juniata,	Kilmer,[2]	475	. . .	. . .	. . .	63·1	88	5	38	30	. . .	. . .	. . .	. . .
Lancaster,	Lancaster, A— Franklin and Marshall College,	413	30·09	30·34	29·69	63·4	87	2, 19	36	28	75·2	51·7	23·5	38
Lawrence,	New Castle,[1]	932	. . .	. . .	. . .	64·8	88	7, 15, 19	36	29	73·7	47·4	26·3	41
Lebanon,	Lebanon, A,	458	30·05	30·32	29·68	62·3	88	19	35	28	72·5	50·8	21·7	36
Lehigh,	Coopersburg,[1]	520	. . .	. . .	. . .	60·4	80	19	39	28	68·9	53·1	15·8	29
Luzerne,	Drifton (26 days), A,	1,683	30·03	30·31	29·65	57·4	80	5	30	27	68·1	46·7	21·4	35
Luzerne,	Wilkes-Barre, A,	575	. . .	. . .	. . .	60·3	85	19	32	30	72·5	48·1	24·4	38
McKean,	Smethport, A,	1,500	. . .	. . .	. . .	57·8	83	7	31	28	69·1	46·4	22·7	36
Montgomery,	Pottstown,	150	. . .	. . .	. . .	63·6	86	19	40	28, 30	73·5	53·8	19·7	36
Montgomery,	Skippack, A (26 days),	. . .	. . .	. . .	. . .	62·1	83	5, 19	38	30	73·2	51·0	22·2	35
Northampton,	Easton[1]— Lafayette College,	395	. . .	. . .	. . .	60·4	82	19	37	30	70·2	50·7	19·5	30
Perry,	(Aqueduct) Logania,[2]	367	. . .	. . .	. . .	62·0	89	5	38	27, 30	. . .	. . .	. . .	. . .
Philadelphia,	U. S. Weather Bureau, A,	117	30·05	30·33	29·64	66·0	87	19	44	30	73·8	57·7	16·1	26
Philadelphia,	1529 Centennial Avenue, A,	120	30·06	30·34	29·64	65·7	85	19	43	30	74·2	57·2	17·0	27
Philadelphia,	3011 Locust Street, A,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Pike,	Bloomings Grove,[2]	. . .	. . .	. . .	. . .	55·2	83	5	37	27, 30	. . .	. . .	. . .	. . .
Schuylkill,	Girardville[1],	1,000	30·00	30·29	29·59	59·2	82	19	35	30	68·4	50·5	17·9	32
Snyder,	Selins Grove, A,	455	30·03	30·24	29·84	63·2	89	5	32	30	75·2	51·2	24·0	38
Somerset,	Somerset,[1]	2,250	. . .	. . .	. . .	59·9	90	19, 20	29	30	74·6	48·2	26·4	43
Tioga,	Wellsboro,[2]	1,327	. . .	. . .	. . .	53·2	76	5	28	27	. . .	. . .	. . .	. . .
Union,	Lewisburg, A,	450	30·06	30·35	29·83	60·2	87	19	34	30	72·2	48·2	24·0	39
Warren,	Columbus,	1,410	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Wayne,	Dyberry,[1]	1,100	. . .	. . .	. . .	53·4	80	5	28	27	67·2	43·0	24·2	38
Wayne,	Honesdale,[1]	1,000	. . .	. . .	. . .	55·9	76	5	34	27, 28	65·8	46·1	19·7	29
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	. . .	. . .	. . .	55·9	79	6, 7	33	27	67·5	48·0	19·5	31
Westmoreland,	(Immel Reservoir) Lycippus,[2]	1,490	. . .	. . .	. . .	62·6	82	7	42	29	. . .	. . .	. . .	. . .
Westmoreland,	Ligonier (22 days),	1,750	. . .	. . .	. . .	59·8	87	6	28	29	73·4	46·8	26·6	43
Wyoming,	South Eaton, A,	660	. . .	. . .	. . .	58·0	80	5	36	27	67·9	48·1	19·8	30
York,	York, A,	385	30·03	30·29	29·81	63·3	89	19	36	28	74·9	51·8	23·1	39

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 +

OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR SEPTEMBER, 1893.

Daily Range.				Relative Humidity.	Dew Point.	Precipitation.				Number of Days.			Wind.			Observers.
													Prevailing Direction.			
Greatest.	Date.	Least.	Date.			Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
33	21	8	12	67·2	52·	1·86	. . .	. . .	8	15	10	5	SE	. . .	SE	O. D. Stewart, Weather Bureau
36	5	7	16	. . .	. . .	5·59	. . .	. . .	7	4	17	9	NW	. . .	NW	William Shipe.
. .	. .	. .	. .	. . .	. . .	3·83	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	Franklin Yager.
39	22	4	13	. . .	. . .	1·85	. . .	. . .	8	. .	. .	. .	. .	. . .	. .	Dr. C. B. Dudley.
24	21	4	13	. . .	. . .	2·76	. . .	. . .	8	7	13	10	NW	NW	NW	A. H. Boyle.
40	3, 21	9	12	. . .	. . .	1·92	. . .	. . .	9	13	8	9	S	W	W	Prof. J. A. Stewart.
37	3	9	14	81·6	51·0	2·89	. . .	. . .	10	8	10	13	NW	SE	NW	Charles Beecher.
32	27	10	6, 14, 20	. . .	. . .	2·70	. . .	. . .	10	2	19	9	SW	SW	SW	G. W. T. Warburton
. .	. .	. .	. .	. . .	. . .	3·51	. . .	. . .	8	11	12	8	W	W	W	J. C. Hilsman.
34	5	7	8	88·9	55·2	3·67	. . .	. . .	8	9	13	8	NE	NW	W	J. L. Heacock.
40	5	8	12	. . .	. . .	2·26	. . .	. . .	11	5	15	10	S	. . .	S	E. C. Lorents.
36	7	7	13	90·7	52·7	2·10	. . .	. . .	10	6	13	11	NW	. . .	W	T. B. Lloyd.
39	22	5	14	. . .	. . .	3·85	. . .	. . .	8	16	6	8	W	W	W	F. C. Wintermute.
43	5	7	12	75·9	52·1	2·22	. . .	. . .	11	4	15	11	W	W	W	Prof. Wm. Frear.
27	5, 21	6	14	69·7	53·3	2·58	. . .	. . .	8	14	8	8	NW	W, NW	NW	J. C. Green, D.D.S.
40	21	9	14	. . .	. . .	3·67	. . .	. . .	7	10	12	8	W	W	W	W. T. Gordon.
34	22	8	14	. . .	. . .	4·24	. . .	. . .	9	12	9	9	N	. . .	SW	B. P. Kirk.
33	22	8	14	78·3	52·1	3·01	. . .	. . .	8	13	4	13	NW	. . .	NW	Knowles Croskey.
. .	. .	. .	. .	. . .	. . .	1·35	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	Harry Alger.
34	21	6	13	. . .	. . .	3·21	. . .	. . .	8	. .	17	9	W	SW	NW	Nathan Moore.
41	5	5	12, 23	. . .	. . .	3·70	. . .	. . .	9	8	9	13	W	W	W	Prof. J. A. Robb.
34	5	7	14	88·8	51·3	2·65	. . .	. . .	9	10	14	6	W	. . .	NW	Prof. J. G. Cope.
36	2	11	12	. . .	. . .	0·57	. . .	. . .	2	4	18	5	S	S	S	Chas. Graves.
33	9	8	5	. . .	. . .	0·72	. . .	. . .	7	11	13	6	SW	. . .	SW	J. G. Apple.
30	22	5	13	. . .	. . .	2·16	. . .	. . .	9	8	13	9	Calm.	SW	Calm.	J. E. Pague.
32	22	6	11	79·0	53·0	1·74	. . .	. . .	10	9	9	12	W	. . .	W	F. Ridgway, Weather Bureau.
. .	. .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	Prof. Susan J. Cunningham.
. .	. .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	C. F. Sweet.
29	21	6	5	7 ·0	51·0	1·13	. . .	. . .	7	5	16	9	SW	. . .	SW	P. Wood, Weather Bureau.
31	1	6	11	. . .	. . .	1·30	. . .	. . .	7	22	4	4	NW	NW	W	Wm. Hunt.
37	21	2	13	. . .	. . .	2·10	. . .	. . .	7	13	4	7	NE	SW	SW	G. W. Ludwig.
. .	. .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	T. F. Sloan.
43	22	8	12	. . .	. . .	3·50	. . .	. . .	10	14	5	11	W	. . .	W	Prof. W. J. Swigart.
. .	. .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	Prof. S. C. Schmucker
. .	. .	. .	. .	. . .	. . .	2·50	. . .	. . .	9	2	15	13	W	W	W	R. J. Mickey.
38	22	11	11	81·1	5 ·3	2·73	. . .	. . .	7	14	9	7	W	. . .	W	W. E. Bushong.
41	1, 2	9	25	. . .	. . .	1·01	. . .	. . .	5	9	11	10	SE	W	W	Wm. T. Butz.
36	22	8	4	85·6	56·2	3·70	. . .	. . .	11	9	13	8	SW	. . .	NE, NW	G. W. Hayes, C.E.
29	22	6	23	. . .	. . .	1·21	. . .	. . .	8	10	11	9	NE	NW	NE	Dr. M. H. Boye
35	4	8	14	82·0	57·0	4·19	. . .	. . .	7	4	11	11	. .	. . .	. .	J. R. Wagner.
38	22	11	14	. . .	. . .	3·74	. . .	. . .	10	15	3	12	W	. . .	W	A. W Betterly.
36	1	8	16	. . .	. . .	2·92	. . .	. . .	9	3	17	10	SE	. . .	W	Armstrong & Brownell.
36	22	6	15	78·0	55·0	3·69	. . .	. . .	9	10	8	6	NW	NW	NW	Charles Moore, D.D.S
35	22	7	20	. . .	. . .	2·94	. . .	. . .	7	9	10	7	W	. . .	W	B. W. Dambly.
30	25	10	14	. . .	. . .	2·92	. . .	. . .	6	7	14	9	. .	. . .	. .	J. W. Moore.
. .	. .	. .	. .	. . .	. . .	2·66	. . .	. . .	10	11	14	5	N	. . .	N	Richard Callin.
26	22	6	26	70·0	53·0	3·76	. . .	. . .	10	10	9	11	NW	. . .	NW	L. M. Dey, Weather Bureau.
27	4	7	23	74·3	53·8	3·96	. . .	. . .	9	11	10	9	NW	. . .	NW	John Comly.
. .	. .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	R. alph L. Paddock.
. .	. .	. .	. .	. . .	. . .	2·61	. . .	. . .	7	. .	. .	. .	. .	. . .	. .	John Grathwohl.
32	5, 22	9	8, 14, 23	. . .	. . .	3·10	. . .	. . .	9	10	12	8	NW	NW	NW	E. C Wagner.
38	30	10	15	93·2	58·6	3·12	. . .	. . .	5	. .	21	9	SW	. . .	SW	J. M. Boyer,
43	5	10	12	. . .	. . .	3·06	. . .	. . .	6	9	7	14	SW	SW	SW	W. M. Schrock.
. .	. .	. .	. .	. . .	. . .	2·03	. . .	. . .	7	3	13	14	N	. . .	W	H. D. Deming
39	3	9	13	92·2	52·0	1·74	. . .	. . .	10	13	10	7	S	. . .	W	Prof. W. G. Owens.
. .	. .	. .	. .	. . .	. . .	. . .	. . .	. . .	. .	. .	. .	. .	. .	. . .	. .	Wm. Loveland.
38	3, 9	6	14	. . .	. . .	3·58	. . .	. . .	9	5	16	9	NW	NW	NW	Theodore Day.
29	5	9	23	. . .	. . .	2·83	. . .	. . .	9	. .	. .	. .	. .	. . .	. .	John Torrey.
33	6	8	14	. . .	. . .	2·82	. . .	. . .	11	3	17	10	NW	NW	NW	T. B. Orchard, M.D.
. .	. .	. .	. .	. . .	. . .	1·57	. . .	. . .	7	. .	. .	. .	. .	. . .	. .	Murray Forbes
43	4	8	12, 16	. . .	. . .	2·84	. . .	. . .	4	10	9	3	. .	. . .	. .	J. T. Ambrose
30	22	7	14	. . .	. . .	2·21	. . .	. . .	8	13	7	10	NW	. . .	NW	B. M. Hall.
39	22	10	11	86·8	57·4	1·57	. . .	. . .	8	11	11	8	NW	. . .	NW	Mrs. L. H. Grenewald.

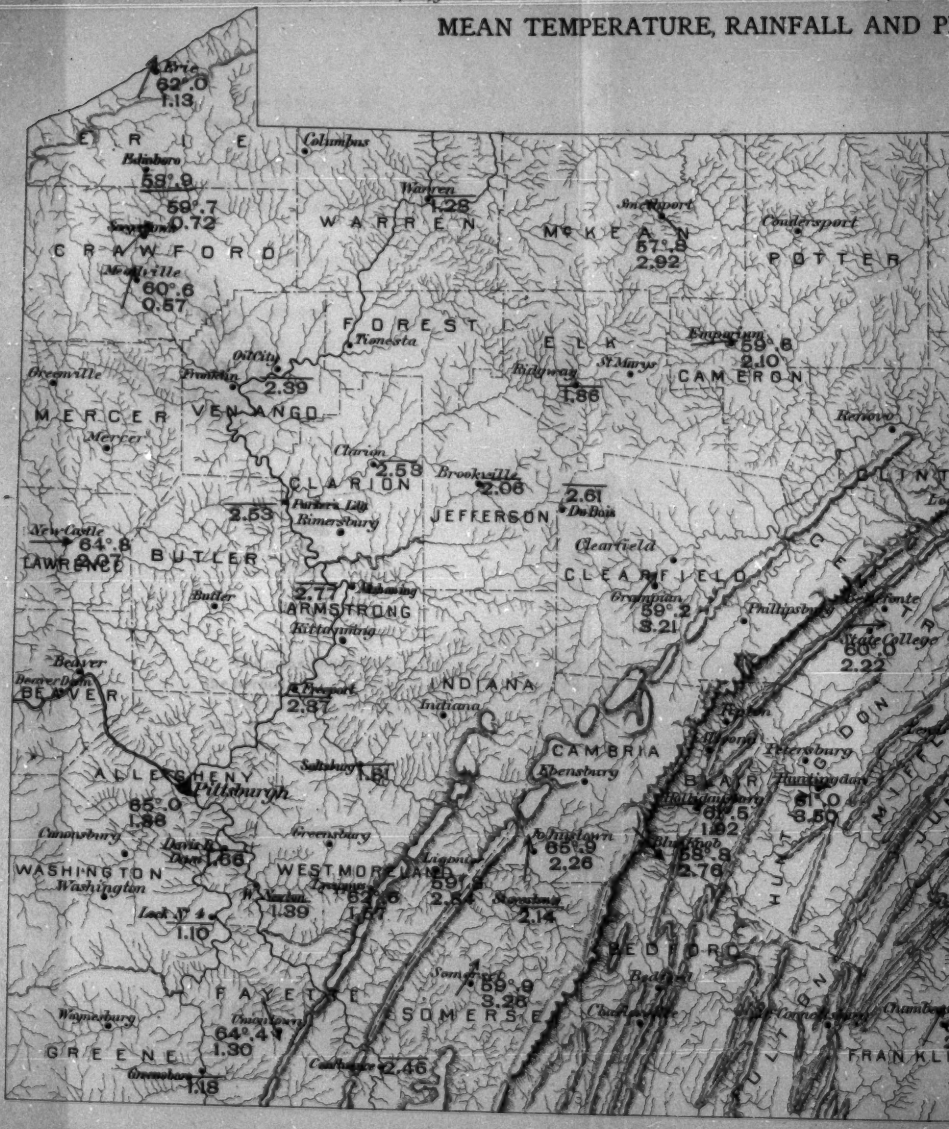
[1] 7 + 9 + 4. [2] Mean of 8 + 8 + 2. [3] Mean of 7 + 7 + 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,	.06						.71								1.13	.11			.15				.14		.31							2.61
Browers Lock,	.23	.08						.22						.26	.08	1.87			.14							.53						3.41
Coatesville,	.28					.01		.03						.46	1.51							.09			.29							3.67
Coopersburg,	.33						.50							.57	1.10	.46			.07				.03		.17							3.93
Doylestown,	.24						.34							.59	1.18	.45			.02						.23							3.95
Dyberry,							.71							.15	1.60	.08		.07	.17				.09		.46		.05					3.58
Easton,		.25						.71								1.55			.22				.02		.27							2.92
Forks of Neshaminy,	.35						.47							.60	1.18	.31			.12				.01		.47							3.51
Frederick,	.30						.57							.38	1.33	.19			.03						.30							3.10
Hamburg,	.48						1.30								2.81	.31			.08				.04		.57							5.59
Honesdale,	.04						.58							.16	1.17	.19	.02		.19				.08		.40							2.83
Kennett Square,	.30	.03				.07								.84	1.92	.02			.07				.20		.79							4.24
Lansdale,	.35						.65							.43	1.63				.85						.21							3.52
Mauch Chunk,	.06							.78						.43	1.33	.60		.10					.01		.54							3.85
Ottsville,	.26	.05					.63							.28	.92	.64			.08				.05		.07							3.04
Philadelphia, a†	.24	.04										.01		.42	1.95	.24			.09	.02			.01		.74							3.76
Philadelphia, b,	.30	.05												.55	1.81	.23			.09	.01					.91	.01						3.96
Philadelphia, c,																																
Phœnixville,	.26	.02						.24						.37	1.68	.05									.38	.01						3.01
Point Pleasant,	.24						.56							.15	.93	.48			.08						.23							3.01
Pottstown,	.25						.87							.30	1.85	.18			.04	.03		.02			.15							3.69
Quakertown,	.36	.03					.48							.53	1.53	.60			.07						.07							3.67
Reading,	.20					.01		.88						.19	2.18	.30			.04				.01		.02							3.83
Salem Corners,		.07					.80							.16	.06	1.04		.07	.25				.02	.11	.18	.12						2.82
Seisholtzville,	.31						.48							.48	1.32	.48									.18							3.19
Skippack,	.28	*					.64		*	*	*			.32	.99	.27			.06						.38							2.94
Smith's Corner,	.25	.03					.60							.44	.98	.48			.08						.23							3.09
Swarthmore,																																
West Chester,	.34	.01	*	*	*	*	*	.02	*	*				.15	1.72							.07			.26	.01						2.58
Westtown,	*	*	*	*	*	*	*	*	*	*				.25	1.10																	1.35
Susquehanna Basin.																																
Altoona,						.62		.01					.18	.34		.18					*		.20	.13	.25	*						1.83
Aqueduct,					.28	.46	.09					.02	.42	.30	.64	.07							.10		.28							2.66
Bloomsburg,							.39	.02						.14	1.75	.04		.02					.14	.01	.24							2.65
Blue Knob,						.64						.13		.80	.08							.28	.26		.60							2.76
Carlisle,	.01					.47							.48	.96	.08	.21						.04			.20	.11						2.56
Drifton,		.13	*				1.24			*				1.00	1.00	.22	*							*	.45	.15						4.19
Emporium,		.10		.02			.35						.28	.06	.30			.05	.08				.32		.54							2.10
Girardville,							.63						.10	.19	1.29	.30		.04	.08				.04		.43							3.10
Grampian,	*	*	*	*	1.12		.36					.12	.11	.32	.03								.35		.80							3.21
Harrisburg,†	.03		.02		.50		.06					.15	.59	.09	.21								.24		.07							1.74
Hollidaysburg,						.50	.12					.18	.32	.13	.08	.06							.31		.22							1.70
Huntingdon,						1.14	.51					.13	.25	.30	.46	.07			.01				.45		.18							3.50
Kilmer,				.01	.25	.33							.22	.01	1.00	.06							.06		.36							2.90
Lancaster,	.87					.20								.37	.85	.19						.12			.25							2.78
Lebanon,	.10					.10	.20	.04					.03	.17	2.56	.39			.02				.06		.12							3.79
Le Roy,							.90						.05	.10	.80	.05		.18	.20				.22		.23				.03			2.70
Lewisburg, †							.27						.22	.28	.13	.56		.02	.02				.21	.30	.24							1.74
Lock Haven,					.03		.83						.30	.14	1.43	.06			.01				.30		.60							3.70
Selins Grove,							.74							.15	1.79	.10									.34							3.12
South Easton,							.67							.06	.90	.07		.06					.06		.32				.07			2.21
State College,						.24	.02					.17	.24	.08	.28	.04			.01				.32	.01	.81							2.22
Wellsboro,							1.20						.02		.36			.05	.20				.08		.12							2.03
Wilkes-Barre,		.05					1.53							.03	1.09	.16		.05		.48			.16		.20				.06			3.74
Wyoss,							1.85					.04	.48	.02			.41						.18	.22	.03		.14	.10				2.89
York,	.10					.27							.23	.11	.41	.11			.19				.15		.15							1.57

† U. S. Weather Bureau Stations. * Missing.

RING SEPTEMBER, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Beaver Dam,						.53		.82			.07		.04	.11	.08				.02					.21	.19	.06						2.06
Brookville,						.70		.05				.01	.11	.38	.01				.14					.40	.60	.05						2.53
Clarion,		.08																														
Columbus,								.80				.01	.05	.55						.04			.10	.03	.30	.53						2.46
Confluence,		.05												.40						.24			.33	.30	.35	.04						1.66
Davis Island Dam,						.60		.19				.01	.05	.55					.08				.13	.52	.57	.04						2.61
DuBois,						.50						.06	.02	.15	.24								.25	.05	.25	.50			.10			2.37
Freeport,								.27						.25	.12							.07	.25		.61							1.18
Greensboro,																																1.57
Immel Reservoir,												.09	.03	.40		.05			.18	.09				.41								2.26
Indiana,				.01	.01	.42	.37	*	*					.04							*	*	*	.38	*	*	.60					2.84
Johnstown,							1.22							.16		.06			.06					.22	.22	.38						1.10
Ligonier,																																
Lock No. 4,						1.03							.08	.30		.03			.04					.11	.55	.58	.05						2.77
Mahoning,																								.28	*	*						0.57
Meadville,						.89																		.46	.54					.35		2.07
New Castle,						.52						.20							.09						.47	.67	.07						2.39
Oil City,						.61						.03	.05	.40					.08					.45	.60							2.53
Parker's Landing,						.71		.01					.09	.52	.13				.02						.65				.03			1.86
Pittsburg,†												.02	.01	.23					.20			.40	.32									1.86
Ridgway,						.36	.05						.25	.15				.15				.30		.03	.09							0.72
Saegertown,		.10			.03		.85	.02				.01	.02	.13					.21					.47	.43	.53						1.81
Saltsburg,						.90						.01		.15	.30					.15			.10	.35		.60						2.92
Smethport,				.02			.05												.20	.18				.15		.92						3.26
Somerset,						.73	.15					.06		1.90										.41	.30	.43						2.14
Stoystown,								.40								.60								.18	.02	.86				.07		1.30
Uniontown,												.02	.06	.15										.25	.08	.09						1.28
Warren,		.06						.03					.04		.04	.05	.11		.32	.27		.05		.13	.10	.40	.02					1.39
West Newton,													.09	.10		.01				.61												
Potomac Basin.																																2.30
Chambersburg,					.51							.27	1.10	.08	.23									.08	.03							
McConnellsburg,																																
Lake Basin.																																
Erie,†												.02			.17	.14		.06	.45					.05		.24						1.13

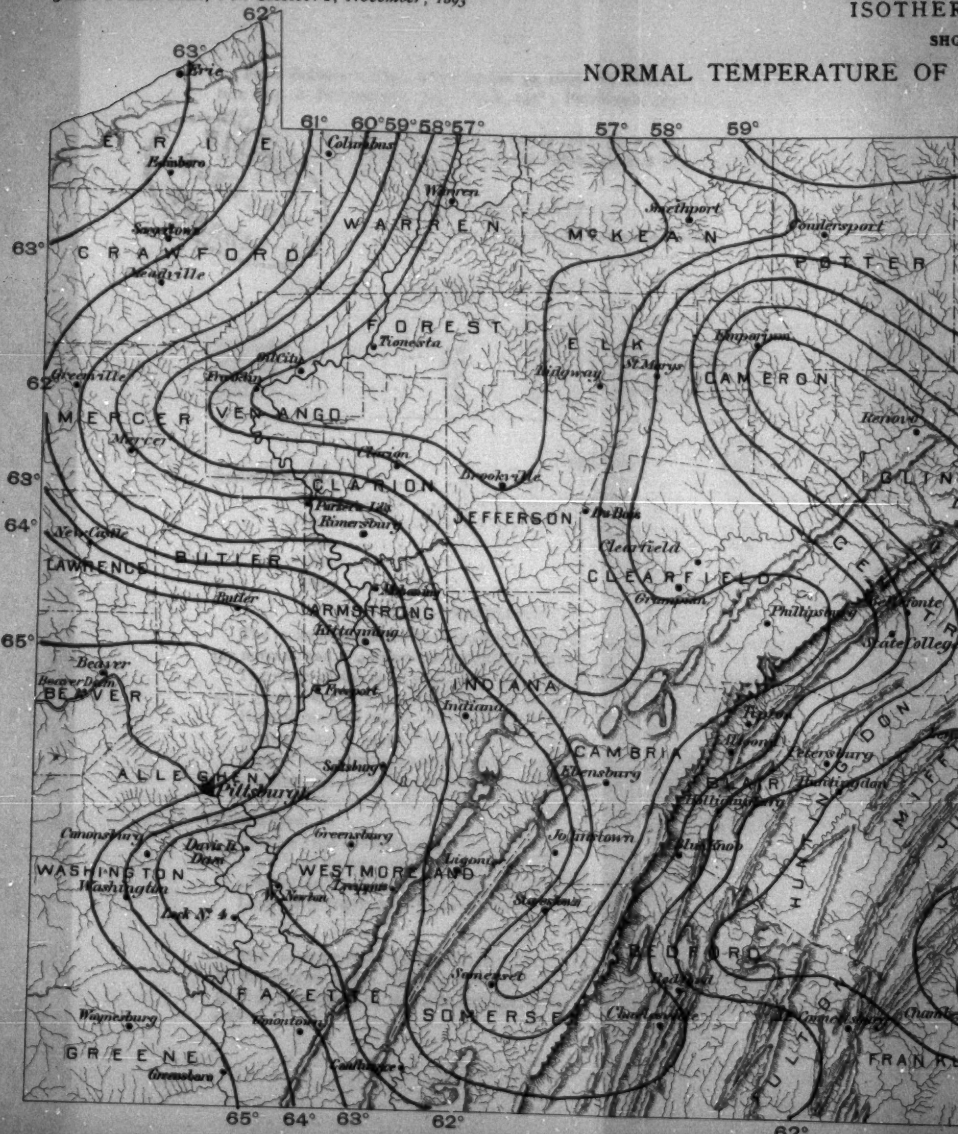

MEAN TEMPERATURE, RAINFALL AND P
Erie
62°.0
1.13
ERIE
Columbus
Edinboro
58°.9
59°.7
0.72
Warren
1.28
WARREN
McKEAN
57°.8
2.92
Smethport
Coudersport
POTTER
CRAWFORD
Meadville
60°.6
0.57
FOREST
ELK
Emporium
59°.8
2.10
Tionesta
St Marys
CAMERON
Oil City
2.39
Franklin
Oleanville
Ridgway
1.86
MERCER
VENANGO
Mercer
Clarion
2.59
Brookville
2.08
2.61
CLARION
Parker's Lily
Rimersburg
2.53
JEFFERSON
DuBois
New Castle
64°.8
2.07
LAWRENCE
BUTLER
Clearfield
CLEARFIELD
Butler
2.77
Mahoning
ARMSTRONG
Kittanning
Curwensville
59°.2
3.21
Phillipsburg
State College
60°.0
2.22
Beaver
Beaver Falls
BEAVER
Freeport
2.37
INDIANA
Indiana
CAMBRIA
Ebensburg
ALLEGHENY
Pittsburgh
65°.0
1.88
Saltsburg
1.82
Hollidaysburg
61°.5
1.62
Huntingdon
61°.0
3.50
Canonsburg
Greensburg
Johnstown
65°.9
2.26
Blairsville
58°.8
2.78
WASHINGTON
Washington
WESTMORELAND
Latrobe
59°.8
2.84
Somerset
2.14
Lock № 4
1.10
Mt. Pleasant
1.39
1.67
BEDFORD
Bedford
Somerset
59°.9
3.26
FAYETTE
Waynesburg
Uniontown
64°.4
1.30
SOMERSET
GREENE
Carnegie
2.45
Greensboro
1.18
FRANKLI

PREVAILING WIND DIRECTION FOR SEPTEMBER. 1893

ISOTHER

SHO

NORMAL TEMPERATURE OF

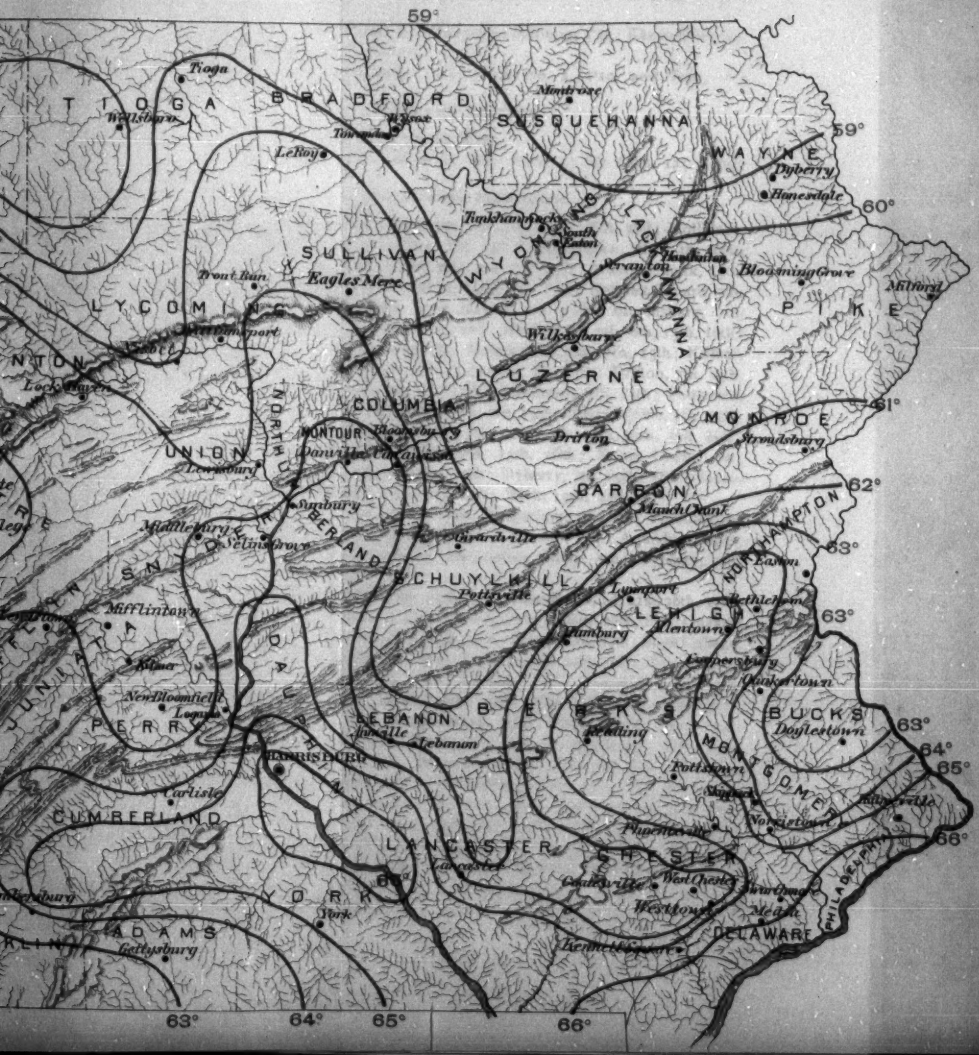


IERMAL LINES,

SHOWING THE

OF PENNSYLVANIA FOR SEPTEMBER.

State Weather Service.



From January 1, 1893, to September 30, 1893, the deficiency in temperature was, at Philadelphia, 315°; York, 445°; Pittsburgh, 404°, and at Erie, 403°.

For the same period the deficiency in precipitation was, at Philadelphia, 2·99; York, 7·03; Harrisburg, 9·48, and at Pittsburgh and Erie an excess of 0·99 and 0·96 inch, respectively.

EXCESSIVE PRECIPITATION.

[One inch in one hour, or two and one-half inches in twenty-four hours.]

Stations.	Amount. (Inches and Hundredths.)	Time.		Date.
		h.	*m.*	
Philadelphia,	1·36	1	—	15th, 4.58 to 5.58 p. m.
Lebanon,	2·56	3	25	15th, 2.20 p. m. to 5.45 p. m.
Coatesville,	2·51	2	30	15th, 5.00 p. m. to 7.30 p. m.
Hamburg,	2·81	—	—	15th, time not given.
Dyberry,	2·00	0	30	15th, 1.40 p. m. to 2.10 p. m.

	Mean Temperature.	*Mean Precipitation. Inches.*
September, 1888,	59°·0	4·84
1889,	61°·9	5·05
1890,	62°·0	4·57
1891,	66°·4	2·39
1892,	62°·3	2·81
1893,	60°·9	2·67

TEMPERATURE.

The mean temperature for September, 1893, was 60°·9, which is 2°·02 below the normal, and 1°·4 below the corresponding month of 1892.

The mean of the daily maximum and minimum temperatures, 71°·7 and 50°·7, gives a monthly mean of 61°·2, with an average daily range of 21°·0.

Highest monthly mean, 66°·0 at Philadelphia. [Weather Bureau.]

Lowest monthly mean, 53°·2 at Wellsboro.

Highest temperature recorded during the month, 90° on the 5th at Huntingdon, on the 19th at Carlisle, and on the 19th and 20th at Somerset.

Lowest temperature, 26° on the 29th at New Castle, and on the 30th at Huntingdon.

Greatest local monthly range, 63° at Hollidaysburg.

Least local monthly range, 41° at Coopersburg.

Greatest daily range, 45° at Huntingdon on the 22d.

Least daily range, 2° at Chambersburg, on the 13th.

BAROMETER.

The mean pressure for the month, 30·04, is about ·04 below the normal. At the United States Weather Bureau Stations, the highest observed was 30·38 at Harrisburg on the 27th, and the lowest 29·64 at Philadelphia on the 16th.

PRECIPITATION.

The average rainfall, 2·67 inches for the month, is a deficiency of 0·86 inch.

The largest monthly totals in inches were Hamburg, 5·59; Kennett Square, 4·24, and Drifton, 4·19 inches.

The least were Saegertown, 0·72; Lock No. 4, 1·10, and Erie, 1·13 inches.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: rainy days, 8; clear days, 9; fair days, 12; cloudy days, 9.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 5th, 6th, 7th, 15th, 16th, 22d; Hollidaysburg, 6th, 7th, 15th, 22d; Le Roy, 7th, 14th; Quakertown, 7th, 15th, 16th; Johnstown, 5th, 16th, 22d; Emporium, 5th, 7th, 15th; Mauch Chunk, 15th, 16th; State College, 7th; Coatesville, 15th, 22d, 25th; Kennett Square, 7th, 15th, 22d; Phœnixville, 7th; Lock Haven, 7th, 15th; Bloomsburg, 7th, 15th; Saegertown, 6th; Carlisle, 7th, 22d; Harrisburg, 5th, 6th, 15th, 16th; Uniontown, 22d; Chambersburg, 6th; Huntingdon, 6th, 7th, 15th; Kilmer, 5th, 6th, 15th, 16th; Lancaster, 15th; Lebanon, 7th, 15th; Drifton, 7th, 14th, 15th, 16th, 25th; Wilkes-Barre, 7th, 15th; Smethport, 7th, 15th; Pottstown, 7th, 15th; Skippack, 7th; Aqueduct, 5th, 7th, 15th; *Philadelphia*, 7th, 15th, 16th, 22d, 25th; [Centennial Avenue], 7th, 14th, 15th, 16th, 20th, 22d, 25th; Blooming Grove, 7th; Girardville, 7th, 15th, 16th; Selins Grove, 7th; Somerset, 7th, 19th; Wellsboro, 7th, 15th; Dyberry, 7th, 15th, 16th; Salem Corners, 7th, 15th; South Eaton, 7th, 15th; York, 15th, 22d.

Hail.—Blue Knob, 7th; Wysox, 7th; Emporium, 5th, 7th; Phœnixville, 7th; Lock Haven, 15th; Bloomsburg, 7th; Lebanon, 15th; Aqueduct, 15th; Blooming Grove, 7th; Girardville, 7th; Selins Grove, 7th; Dyberry, 7th, 15th.

Frost.—Pittsburgh, 27th, 28th, 29th, 30th; Blue Knob, 2d, 21st, 26th, 27th, 28th, 29th, 30th; Hollidaysburg, 30th; Wysox, 30th; Le Roy, 26th, 27th; Quakertown, 28th; Johnstown, 27th, 28th, 29th, 30th; Emporium, 29th; State College, 27th, 30th; Grampian, 26th, 27th, 28th; Lock Haven, 29th, 30th; Bloomsburg, 30th; Saegertown, 28th, 29th, 30th; Carlisle, 21st; Uniontown, 3d, 27th, 28th, 29th; Kilmer, 30th; New Castle, 25th, 26th, 27th, 28th, 29th, 30th; Lebanon, 18th, 27th, 28th; Coopersburg, 27th; Drifton, 3d, 26th, 27th; Wilkes-Barre, 28th, 29th, 30th; Smethport, 26th; Skippack, 7th, 28th, 29th, 30th; Aqueduct, 3d, 26th, 30th; Blooming Grove, 20th, 21st, 22d, 23d, 24th, 25th, 26th, 27th, 28th, 29th, 30th; Girardville, 3d, 6th, 21st, 26th, 27th, 28th, 29th, 30th; Selins Grove, 26th, 27th, 29th, 30th; Somerset, 3d, 4th, 28th, 29th, 30th; Wellsboro, 3d, 9th, 21st, 26th, 27th, 28th; Lewisburg, 30th; Dyberry, 3d, 21st, 27th, 28th, 30th; Honesdale, 3d, 26th, 27th, 28th, 29th, 30th; Salem Corners, 26th, 27th, 28th, 29th; Ligonier, 29th, 30th; York, 3d, 28th, 29th, 30th.

Snow.—Girardville, 29th.

Aurora.—Johnstown, 8th; Coatesville, 21st; Dyberry, 8th; Salem Corners, 2d, 3d, 7th, 9th, 10th, 11th, 12th, 30th.

Coronæ.—Emporium, 22d, 23d; Lebanon, 24th; Philadelphia [Centennial Avenue], 26th; York, 26th.

Solar Halo.—Johnstown, 26th; Bloomsburg, 30th; Saegertown, 30th; *Philadelphia*, 9th, 30th; [Centennial Avenue], 9th, 10th, 12th, 30th; Wellsboro, 17th, 30th; Salem Corners, 26th.

Lunar Halo.—Blue Knob, 24th; Saegertown, 29th; Somerset, 23d; Wellsboro, 22d.

OBERLIN
COLLEGE
LIBRARY

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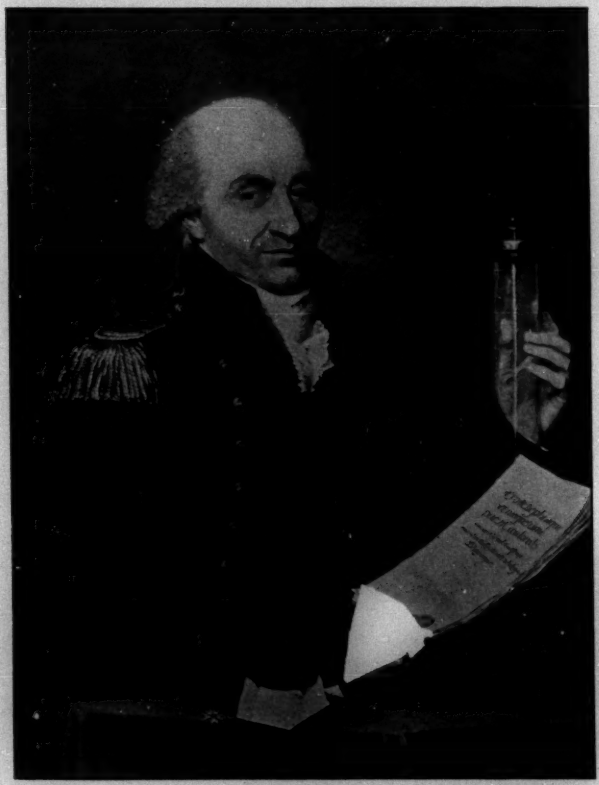

CHARLES A. COULOMB.

(1736–1806.)